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(54) SYSTEMS, METHODS, AND APPARATUS TO PREHEAT WELDING WIRE

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(56) **References Cited**

U.S. PATENT DOCUMENTS

2,365,958	A	12/1944	Holslag
2,416,047	A	2/1947	Dolan

(Continued)

FOREIGN PATENT DOCUMENTS

AT	413801	6/2006
CA	2072711	12/1992

(Continued)

OTHER PUBLICATIONS

"ALT 304," Miller—The Power of Blue, Jun. 2001.

(Continued)

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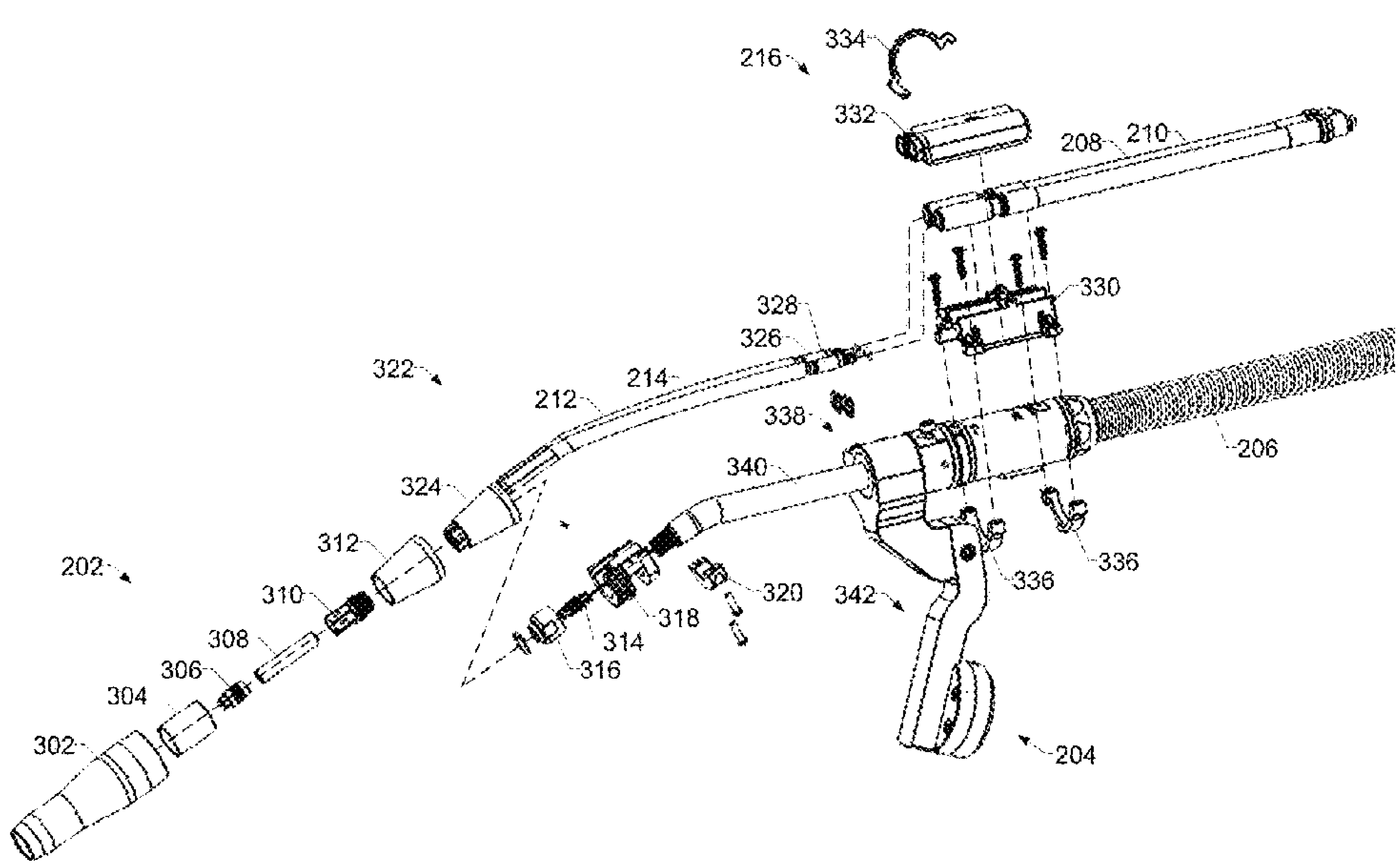
(57) **ABSTRACT**

Systems, methods, and apparatus to preheat weld wire are disclosed. An example welding torch includes a first contact tip configured to conduct welding current to a consumable electrode, a second contact tip configured to conduct preheating current to the consumable electrode, and a plurality of liquid cooling assemblies configured to conduct the preheating current and to conduct the welding current to the consumable electrode.

17 Claims, 22 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2,976,462	A	3/1961	Miller	
3,030,495	A	4/1962	Anderson	
3,288,982	A	11/1966	Haruyoshi	
3,549,857	A	12/1970	Carter	
3,725,629	A	4/1973	Vickers	
3,809,853	A	5/1974	Manz	
3,849,871	A	11/1974	Kaunitz	
3,912,980	A	10/1975	Crump	
3,946,349	A	3/1976	Haldeman	
4,160,967	A	7/1979	Beech	
4,188,419	A	2/1980	Detert	
4,222,023	A	9/1980	Beech	
4,329,561	A	5/1982	Schafer	
4,426,565	A	1/1984	Rueter	
4,447,703	A	5/1984	Stol	
4,467,176	A	8/1984	Mizuno	
4,493,971	A	1/1985	Nawa	
4,531,040	A	7/1985	Nawa	
4,536,634	A	8/1985	Nawa	
4,546,234	A	10/1985	Ogasawara	
4,547,654	A	10/1985	Stol	
4,580,026	A	4/1986	Stol	
4,614,856	A	9/1986	Hori	
4,628,182	A	12/1986	Hori	
4,631,385	A	12/1986	Rothermel	
4,667,083	A *	5/1987	Stol	B23K 9/295 219/136
4,675,494	A	6/1987	Dilay	
4,728,761	A	3/1988	Mucha	
4,897,523	A	1/1990	Parks	
4,950,348	A	8/1990	Larsen	
4,954,691	A	9/1990	Parks	
4,973,821	A	11/1990	Martin	
5,001,326	A	3/1991	Stava	
5,043,557	A	8/1991	Tabata	
5,086,207	A	2/1992	Deam	
5,101,086	A	3/1992	Dion	
5,118,028	A	6/1992	Ogawa	
5,140,123	A	8/1992	Mitani	
5,148,001	A	9/1992	Stava	
5,208,433	A	5/1993	Hellegouarc	
5,270,516	A	12/1993	Hamamoto	
5,278,390	A	1/1994	Blankenship	
5,315,089	A	5/1994	Hughes	
5,319,179	A	6/1994	Joecks	
5,343,023	A	8/1994	Geissler	
5,349,156	A	9/1994	Madigan	
5,352,871	A	10/1994	Ross	
5,367,138	A	11/1994	Moss	
5,412,184	A	5/1995	McGaffigan	
5,461,215	A	10/1995	Haldeman	
5,466,916	A	11/1995	Iguchi	
5,504,309	A	4/1996	Geissler	
5,521,355	A	5/1996	Lorentzen	
5,526,561	A	6/1996	McGaffigan	
5,644,461	A	7/1997	Miller	
5,710,413	A	1/1998	King	
5,714,738	A	2/1998	Hauschulz	
5,739,506	A	4/1998	Hanton	
5,742,029	A	4/1998	Stava	
5,756,967	A	5/1998	Quinn	
5,760,373	A	6/1998	Colling	
5,773,799	A	6/1998	Maxfield	
5,783,799	A	7/1998	Geissler	
5,844,193	A	12/1998	Nomura	
5,963,022	A	10/1999	Buda	
5,968,587	A	10/1999	Frankel	
5,994,659	A	11/1999	Offer	
6,002,104	A	12/1999	Hsu	
6,008,470	A	12/1999	Zhang	
6,043,471	A	3/2000	Wiseman	
6,051,810	A	4/2000	Stava	
6,077,369	A	6/2000	Kusano	
6,078,023	A	6/2000	Jones	
6,090,067	A	7/2000	Carter	
6,107,602	A	8/2000	Geissler	
6,115,273	A	9/2000	Geissler	
6,160,241	A	12/2000	Stava	
6,169,263	B1	1/2001	Derby	
6,204,476	B1	3/2001	Reynolds	
6,248,976	B1	6/2001	Blankenship	
6,259,059	B1	7/2001	Hsu	
6,265,688	B1	7/2001	Lyshkow	
6,274,845	B1	8/2001	Stava	
6,278,074	B1	8/2001	Morlock	
6,292,715	B1	9/2001	Rongo	
6,331,694	B1	12/2001	Blankenship	
6,359,258	B1	3/2002	Blankenship	
6,479,792	B1	11/2002	Beiermann	
6,486,439	B1	11/2002	Spear	
6,515,259	B1	2/2003	Hsu	
6,559,416	B1	5/2003	Steenis	
6,583,386	B1	6/2003	Ivkovich	
6,596,970	B2	7/2003	Blankenship	
6,624,388	B1	9/2003	Blankenship et al.	
6,642,482	B2	11/2003	Rappl	
6,670,579	B2	12/2003	Davidson	
6,707,001	B1	3/2004	Ulrich	
6,710,297	B1	3/2004	Artelsmair	
6,720,529	B2	4/2004	Davidson	
6,744,012	B2	6/2004	Ueda	
6,747,247	B2	6/2004	Holverson	
6,849,828	B2	2/2005	Aigner	
6,906,284	B2	6/2005	Kim	
6,909,067	B2	6/2005	Davidson	
6,933,466	B2	8/2005	Hutchison	
6,958,263	B2	10/2005	Bhattacharyya	
6,974,931	B2	12/2005	Holverson	
6,974,932	B2	12/2005	Holverson	
6,984,806	B2	1/2006	Huismann	
6,995,338	B2	2/2006	Hutchison	
7,002,103	B2	2/2006	Holverson	
7,105,775	B2	9/2006	Giese	
7,129,443	B2	10/2006	Davidson	
7,145,101	B2	12/2006	Tong	
7,244,905	B2	7/2007	Das	
7,265,320	B2	9/2007	Ou	
7,304,269	B2	12/2007	Fulmer	
7,307,240	B2	12/2007	Holverson	
7,351,933	B2	4/2008	Huismann	
7,381,923	B2	6/2008	Gordon	
7,576,300	B2	8/2009	Giese	
7,683,290	B2	3/2010	Daniel	
8,203,100	B2	6/2012	Ueda	
8,288,686	B2	10/2012	Kaufman	
8,304,693	B2	11/2012	Ma	
8,357,877	B2	1/2013	Ma	
8,487,215	B2	7/2013	Holverson	
8,604,388	B2	12/2013	Dingeldein	
9,095,928	B2	8/2015	Ash	
9,162,312	B2	10/2015	Ma	
9,193,004	B2	11/2015	Enyedy	
9,193,005	B2	11/2015	Ma	
9,403,231	B2	8/2016	Hutchison	
9,409,250	B2	8/2016	Daniel	
9,463,523	B2	10/2016	Roth	
9,539,662	B2	1/2017	Hutchison	
9,669,486	B2	6/2017	Dingeldein	
9,950,383	B2	4/2018	Davidson	
2002/0008095	A1	1/2002	Norrish	
2002/0045970	A1	4/2002	Krause	
2002/0107825	A1	8/2002	Manicke	
2002/0117487	A1	8/2002	Corby	
2002/0117488	A1	8/2002	Arndt	
2003/0010756	A1	1/2003	Enyedy	
2003/0058149	A1	3/2003	Jayadeva	
2004/0010342	A1	1/2004	Thelen	
2004/0069759	A1	4/2004	Davidson	
2004/0182828	A1	9/2004	Schmidt	
2004/0222204	A1	11/2004	Hutchison	
2004/0238511	A1	12/2004	Matus	
2005/0072762	A1	4/2005	Delgado	
2005/0184039	A1	8/2005	Stava	
2005/0218132	A1	10/2005	Wells	

(56) **References Cited**

U.S. PATENT DOCUMENTS

2005/0269306	A1	12/2005	Fulmer	
2006/0138115	A1	6/2006	Norrish	
2006/0163227	A1	7/2006	Hillen	
2006/0163229	A1	7/2006	Hutchison	
2007/0051711	A1	3/2007	Kachline	
2007/0084840	A1	4/2007	Davidson	
2007/0102407	A1	5/2007	Uezono	
2007/0170163	A1	7/2007	Narayanan	
2007/0235434	A1	10/2007	Davidson	
2007/0267394	A1	11/2007	Beck	
2008/0264916	A1	10/2008	Nagano	
2008/0264917	A1	10/2008	White	
2008/0264923	A1	10/2008	White	
2009/0026188	A1	1/2009	Schorghuber	
2009/0039066	A1	2/2009	Centner	
2009/0173726	A1	7/2009	Davidson	
2009/0215302	A1 *	8/2009	Roberts	B23K 9/324 439/350
2010/0012637	A1 *	1/2010	Jaeger	B23K 9/295 219/136
2010/0059493	A1	3/2010	McAninch	
2010/0096373	A1	4/2010	Hillen	
2010/0096436	A1	4/2010	Nangle	
2010/0133250	A1	6/2010	Sardy	
2010/0176104	A1	7/2010	Peters	
2010/0308026	A1	12/2010	Vogel	
2010/0308027	A1	12/2010	Vogel	
2010/0314371	A1	12/2010	Davidson	
2011/0108527	A1	5/2011	Peters	
2011/0114612	A1	5/2011	Holverson	
2011/0163080	A1	7/2011	Beck	
2011/0204034	A1	8/2011	Schartner	
2011/0204035	A1	8/2011	Grossauer	
2011/0297658	A1	8/2011	Peters	
2011/0248007	A1	10/2011	Takeda	
2011/0266269	A1	11/2011	Kachline	
2012/0024828	A1	2/2012	Oowaki	
2012/0061362	A1	3/2012	Davidson	
2012/0074112	A1	3/2012	Kotera	
2012/0097655	A1	4/2012	Daniel	
2012/0248080	A1	10/2012	Hutchison	
2012/0285932	A1	11/2012	Yuan	
2012/0291172	A1	11/2012	Wills	
2012/0298642	A1	11/2012	Lambert	
2013/0112674	A1	5/2013	Mnich	
2013/0112676	A1	5/2013	Hutchison	
2013/0213942	A1	8/2013	Peters	
2013/0264323	A1	10/2013	Daniel	
2013/0270245	A1	10/2013	Holverson	
2014/0008328	A1	1/2014	Enyedy	
2014/0008331	A1	1/2014	Ogborn	
2014/0008339	A1	1/2014	Ogborn	
2014/0008343	A1	1/2014	Ash	
2014/0008344	A1	1/2014	Enyedy	
2014/0008354	A1	1/2014	Pletcher	
2014/0021183	A1	1/2014	Peters	
2014/0021186	A1	1/2014	Denney	
2014/0021187	A1	1/2014	Denney	
2014/0021188	A1	1/2014	Denney	
2014/0034621	A1	2/2014	Daniel	
2014/0034622	A1	2/2014	Barrett	
2014/0035279	A1	2/2014	Narayanan	
2014/0042129	A1	2/2014	Daniel	
2014/0042138	A1	2/2014	Matthews	
2014/0048524	A1	2/2014	Ash	
2014/0116994	A1	5/2014	Peters	
2014/0131321	A1	5/2014	Enyedy	
2014/0158669	A1	6/2014	Davidson	
2014/0177109	A1	6/2014	Curtis	
2014/0183176	A1	7/2014	Hutchison	
2014/0217077	A1	8/2014	Davidson	
2014/0251971	A1	9/2014	Hearn	
2014/0263193	A1	9/2014	Denney	
2014/0263194	A1	9/2014	Narayanan	
2014/0263228	A1	9/2014	Peters	
2014/0263229	A1	9/2014	Peters	
2014/0263230	A1	9/2014	Peters	
2014/0263231	A1	9/2014	Peters	
2014/0263234	A1	9/2014	Peters	
2014/0263237	A1	9/2014	Daniel	
2014/0263241	A1	9/2014	Henry	
2014/0263243	A1	9/2014	Marschke	
2014/0263251	A1	9/2014	Enyedy	
2014/0319103	A1	10/2014	Stabb et al.	
2014/0367370	A1	12/2014	Hutchison	
2014/0374391	A1	12/2014	Cole	
2015/0001184	A1	1/2015	Cole	
2015/0001197	A1	1/2015	Marschke	
2015/0014283	A1	1/2015	Peters	
2015/0028010	A1	1/2015	Peters	
2015/0028011	A1	1/2015	Peters	
2015/0028012	A1	1/2015	Peters	
2015/0083702	A1	3/2015	Scott	
2015/0090703	A1	4/2015	Peters	
2015/0105898	A1	4/2015	Adams	
2015/0151375	A1	6/2015	Peters	
2015/0158105	A1	6/2015	Peters	
2015/0158106	A1	6/2015	Peters	
2015/0158107	A1	6/2015	Latessa	
2015/0158108	A1	6/2015	Peters	
2015/0183044	A1	7/2015	Peters	
2015/0183045	A1	7/2015	Peters	
2015/0209889	A1	7/2015	Peters	
2015/0209905	A1	7/2015	Matthews	
2015/0209906	A1	7/2015	Denney	
2015/0209907	A1	7/2015	Narayanan	
2015/0209908	A1	7/2015	Peters	
2015/0209910	A1	7/2015	Denney	
2015/0209913	A1	7/2015	Denney	
2015/0213921	A1	7/2015	Koide	
2015/0251275	A1	9/2015	Denney	
2015/0273612	A1	10/2015	Peters	
2015/0283638	A1	10/2015	Henry	
2015/0283639	A1	10/2015	Henry	
2016/0074954	A1	3/2016	Marschke	
2016/0074973	A1 *	3/2016	Kachline	B23K 9/285 219/74
2016/0144444	A1	5/2016	Davidson	
2016/0167151	A1	6/2016	Mehn	
2016/0175975	A1	6/2016	Lattner	
2016/0199939	A1	7/2016	Hartman	
2016/0221105	A1	8/2016	Henry	
2016/0288235	A1	10/2016	Davidson	
2016/0318112	A1	11/2016	Hutchison	
2017/0080512	A1	3/2017	Centner	
2017/0165778	A1	6/2017	Hsu	
2017/0225255	A1	8/2017	Zwayer	
2018/0236585	A1	8/2018	Davidson	

FOREIGN PATENT DOCUMENTS

CA	2883947	3/2014
CN	2125475	12/1992
CN	2181354	11/1994
CN	1298778	6/2001
CN	1496774	5/2004
CN	1600486	3/2005
CN	1640603	7/2005
CN	1712168	12/2005
CN	1714978	1/2006
CN	1836818	9/2006
CN	1871093	11/2006
CN	101062530	10/2007
CN	201098775	8/2008
CN	101376191	3/2009
CN	201249331	6/2009
CN	101804495	8/2010
CN	101862886	10/2010
CN	102059476	5/2011
CN	102470473	5/2012
CN	102554418	7/2012
CN	102596475	7/2012
CN	102770228	11/2012
CN	102825370	12/2012

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

CN	202824943		3/2013
CN	104968465		10/2015
DE	2501928		7/1976
DE	19808383		9/1999
DE	212004000048		6/2006
EP	0150543		8/1985
EP	0194045		9/1986
EP	0204559		12/1986
EP	0387223		9/1990
EP	0936019	A2	8/1999
EP	0936019	A3	3/2001
EP	1232825		8/2002
EP	2218537		8/2010
EP	2286949		2/2011
EP	2322315		5/2011
EP	2522453		11/2012
EP	2892680		7/2015
EP	2781291		10/2015
FR	1443701		6/1966
JP	S5719166		2/1982
JP	S57109573		7/1982
JP	S583784		1/1983
JP	S58119466		7/1983
JP	S60108175		6/1985
JP	S60108176		6/1985
JP	S60170577		9/1985
JP	61186172		8/1986
JP	S629773		1/1987
JP	S6471575		3/1989
JP	H03285768		12/1991
JP	H06277840		10/1994
JP	H07204848		8/1995
JP	H1097327		4/1998
JP	H11156542		6/1999
JP	2001276971		10/2001
JP	2003205385		7/2003
JP	2003311409		11/2003
JP	2005034853		2/2005
JP	2006205189		8/2006
JP	2009072814		4/2009
JP	4950819		6/2012
JP	2014176890		9/2014
KR	1020060133016		12/2006
KR	20080009816		1/2008
KR	20100120562		11/2010
KR	1020120027764		3/2012
KR	101497460		3/2015
SU	872102		10/1981
WO	9640465		12/1996
WO	0132347		5/2001
WO	0153030		7/2001
WO	2005030422		4/2005
WO	2014140783		9/2014
WO	2015125008		8/2015

OTHER PUBLICATIONS

"Maxstar 200 SD, DX, and LX," Miller Electric Mfg. Co., Oct. 2003.

Bondy et al., "Graph Theory with Applications," Department of Combinatorics and Optimization, University of Waterloo, 1976, p. 7-8.

Int'l Search Report and Written Opinion for PCT/US2016/065265 dated Mar. 14, 2017 (16 pages).

Int'l Search Report and Written Opinion for PCT/US2018/029770 dated Sep. 12, 2018 (13 pgs.).

Int'l Search Report and Written Opinion for PCT/US2018/036906 dated Oct. 1, 2018 (15 pgs.).

Int'l Search Report and Written Opinion for PCT/US2018/036914 dated Oct. 2, 2018 (14 pgs.).

Int'l Search Report and Written Opinion for PCT/US2018/036915 dated Oct. 1, 2018 (15 pgs).

Int'l Search Report and Written Opinion for PCT/US2018/036919 dated Oct. 2, 2018 (13 pgs.).

International Search Report from PCT application No. PCT/US2014/017864, dated Aug. 22, 2014, 9 pgs.

International Search Report from PCT application No. PCT/US2014/041201, dated Nov. 4, 2014, 11 pg.

International Search Report from PCT application No. PCT/US2014/045872, dated Nov. 4, 2014, 10 pgs.

International Search Report from PCT Application No. PCT/US2014/055529, dated Mar. 6, 2015, 9 pgs.

International Search Report from PCT application No. PCT/US2015/045715, dated Jan. 7, 2016, 12 pgs.

International Search Report from PCT application No. PCT/US2015/055040, dated Feb. 3, 2016, 11 pgs.

International Search Report from PCT application No. PCT/US2015/056121, dated Apr. 4, 2016, 11 pgs.

International Search Report from PCT application No. PCT/US2016/017385, dated Jul. 19, 2016, 13 pgs.

International Search Report from PCT application No. PCT/US2013/073490 dated May 13, 2014, 10 pgs.

International Search Report from PCT application No. PCT/US2013/073863 dated May 2, 2014, 15 pgs.

International Search Report from PCT application No. PCT/US2013/077710 dated May 9, 2014, 12 pgs.

International Search Report from PCT application No. PCT/US2014/014241 dated May 9, 2014, 8 pgs.

Office Action from U.S. Appl. No. 15/498,249 dated Apr. 20, 2018.

PCT International Search Report & Written Opinion of PCT/US2012/063783 dated Mar. 1, 2013, 12 pages.

Canadian Office Action Appln No. 3,005,408 dated Mar. 19, 2019.

Gupta, "A low temperature hydrogen sensor based on palladium nanoparlicles," Published in 2014.

Int'l Search Report and Written Opinion Appln No. PCT/U2019/049109 dated Dec. 2, 2019 (11 pgs).

Int'l Search Report and Written Opinion Appln No. PCT/US2019/050972, dated Nov. 14, 2019, (13 pgs).

Int'l Search Report and Written Opinion for PCT/US2018/035087 dated Sep. 19, 2018 (15 pgs.).

Int'l Search Report and Written Opinion for PCT/US2018/036852 dated Oct. 2, 2018 (17 pgs.).

Int'l Search Report and Written Opinion for PCT/US2018/036898 dated Oct. 1, 2018 (14 pgs.).

Int'l Search Report and Written Opinion for PCT/US2018/036900 dated Oct. 5, 2018 (15 pgs.).

Int'l Search Report and Written Opinion for PCT/US2018/049888 dated Feb. 1, 2019 (14 pgs.).

Int'l Search Report and Written Opinion for PCT/US2018/052384 dated Feb. 12, 2019 (12 pgs.).

Lincoln Electric, "Storing and Redrying Electrodes," Published in 2011.

N.A.: "Drahtgluhe", Aug. 23, 2016 (Aug. 23, 2016), XP055510057, Wikipedia, Retrieved from the Internet: URL:https://de.wikipedia.Org/w/index.php7title=Drahtgl%C3%BChe&oldid=157333005, [retrieved on Sep. 26, 2018], with machine translation, 2 pages.

Non-Final Office Action U.S. Appl. No. 15/343,992 dated Mar. 7, 2019 (18 pgs.).

Non-Final Office Action U.S. Appl. No. 15/498,249 dated Sep. 23, 2019 (43 pgs).

PCT, IPRP, issued in connection with PCT/US2018/036898, dated Dec. 19, 2019, 7 pages.

PCT, IPRP, issued in connection with PCT/US2018/036900, dated Dec. 19, 2019, 7 pages.

Pitrun, "The effect of welding parameters on levels of diffusible hydrogen in weld metal deposited using gas shield rutile flux cored wires," Published in 2004.

Canadian Office Action Appln. No. 3,066,687 dated Mar. 16, 2021.

* cited by examiner

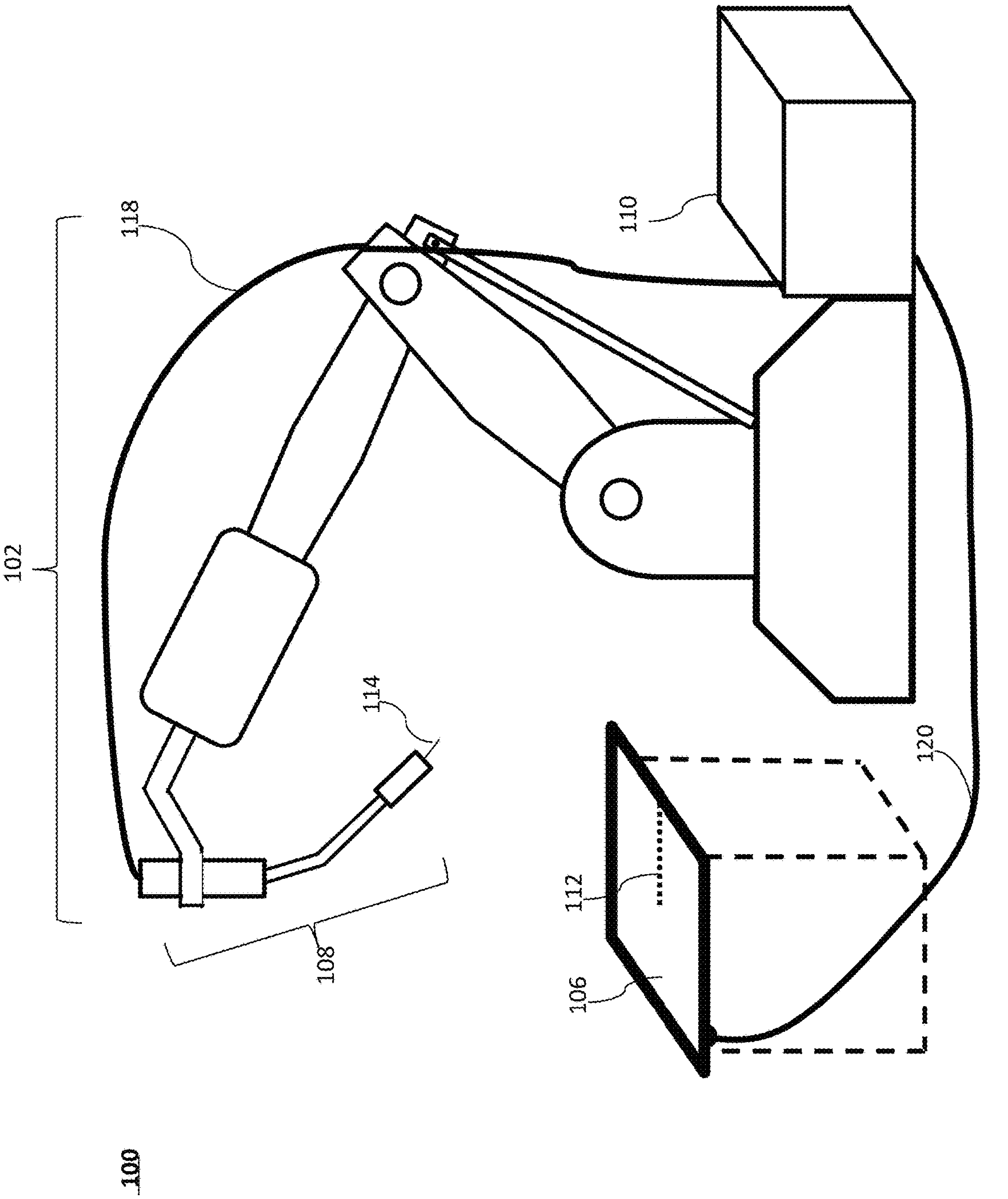


FIG. 1

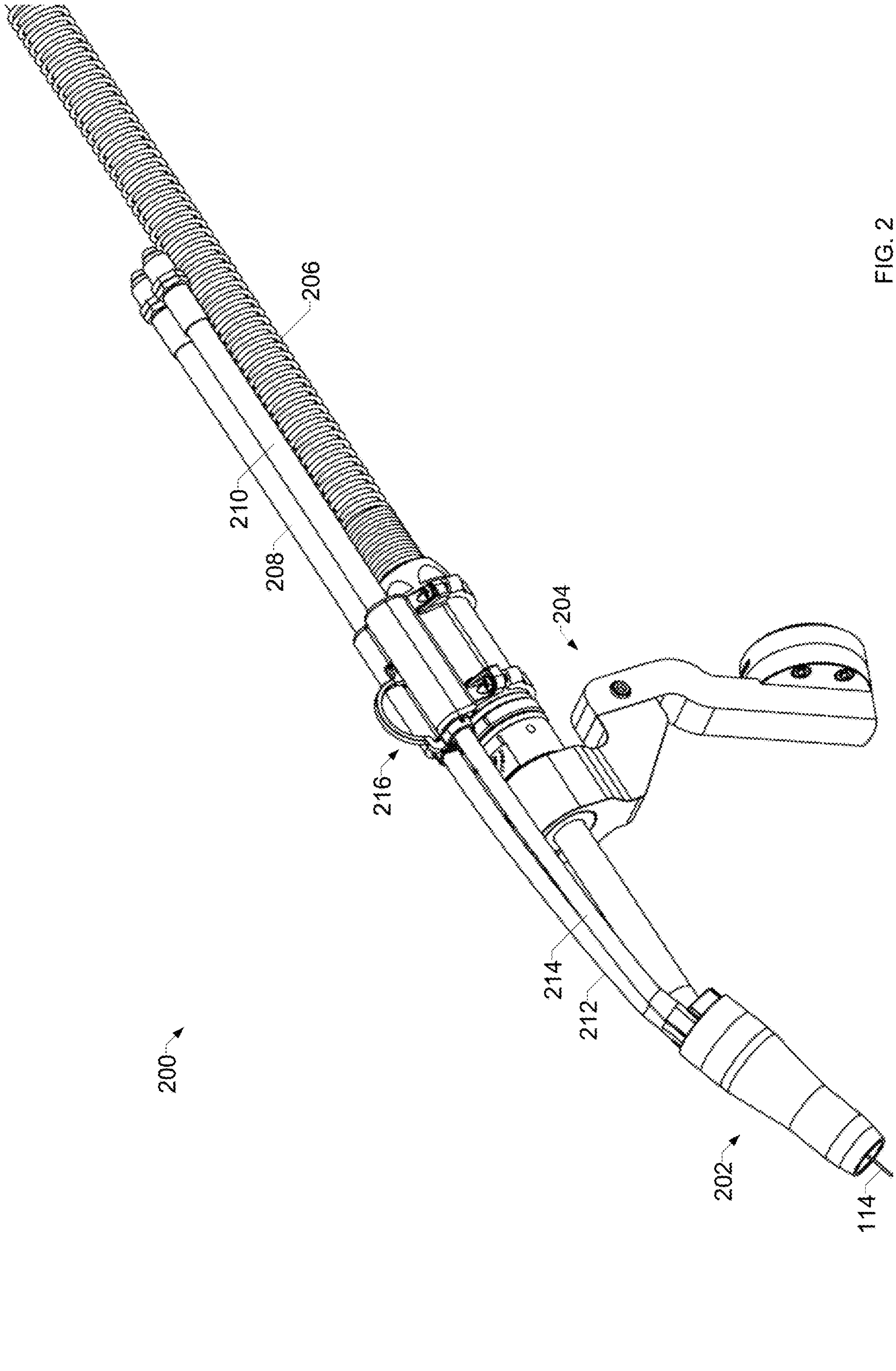
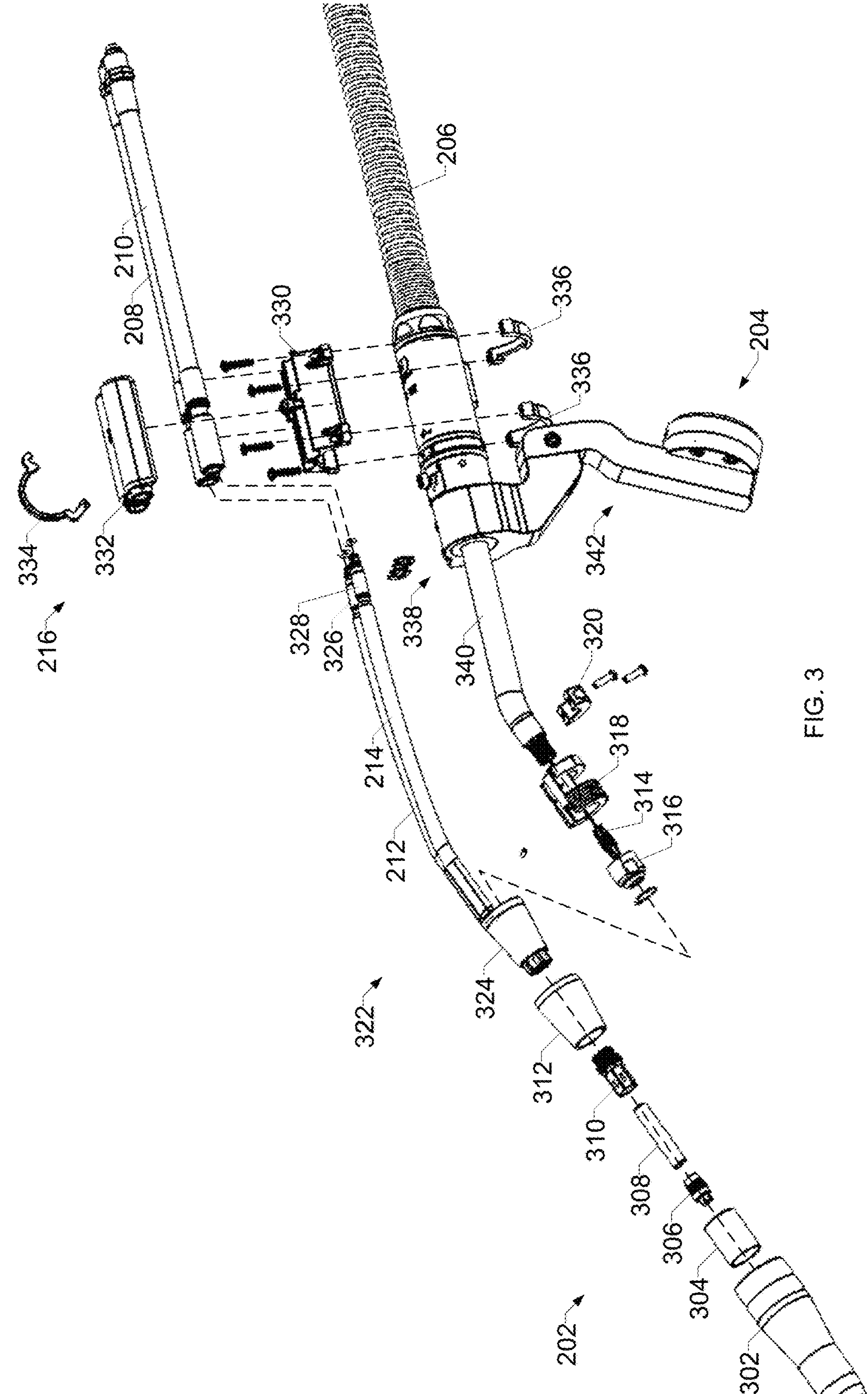


FIG. 2


206
210
208
330
336
336
204
334
332
216
342
338
328
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340
320
318
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214
212
322
324
312
310
308
306
304
202
302

FIG. 3

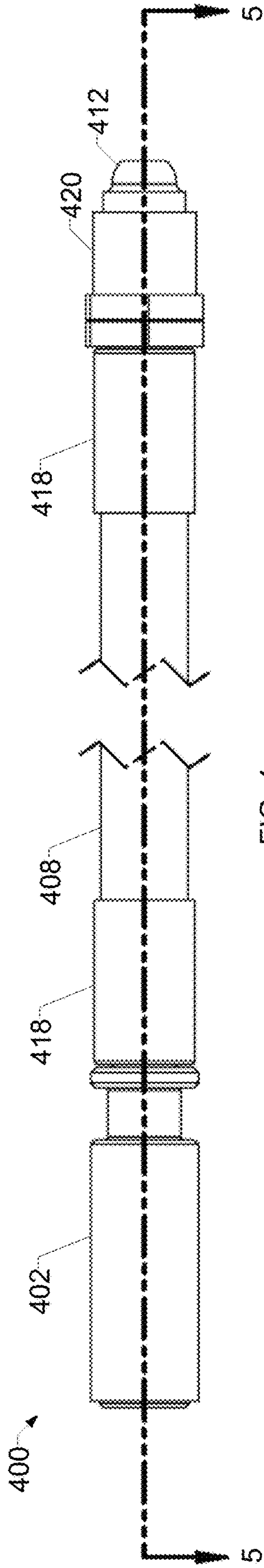

5
412
420
418
408
418
402
400
5

FIG. 4

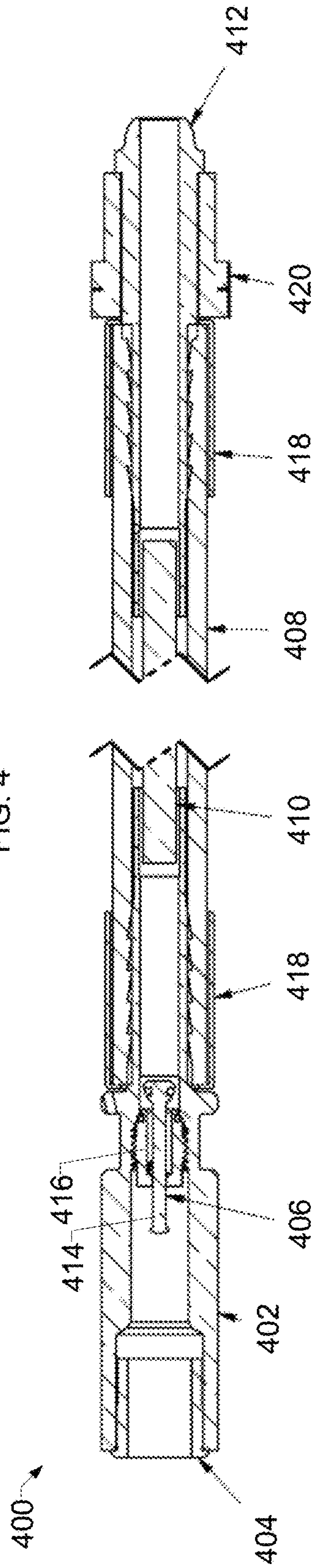

412
420
418
408
410
418
416
406
414
402
400
404

FIG. 5

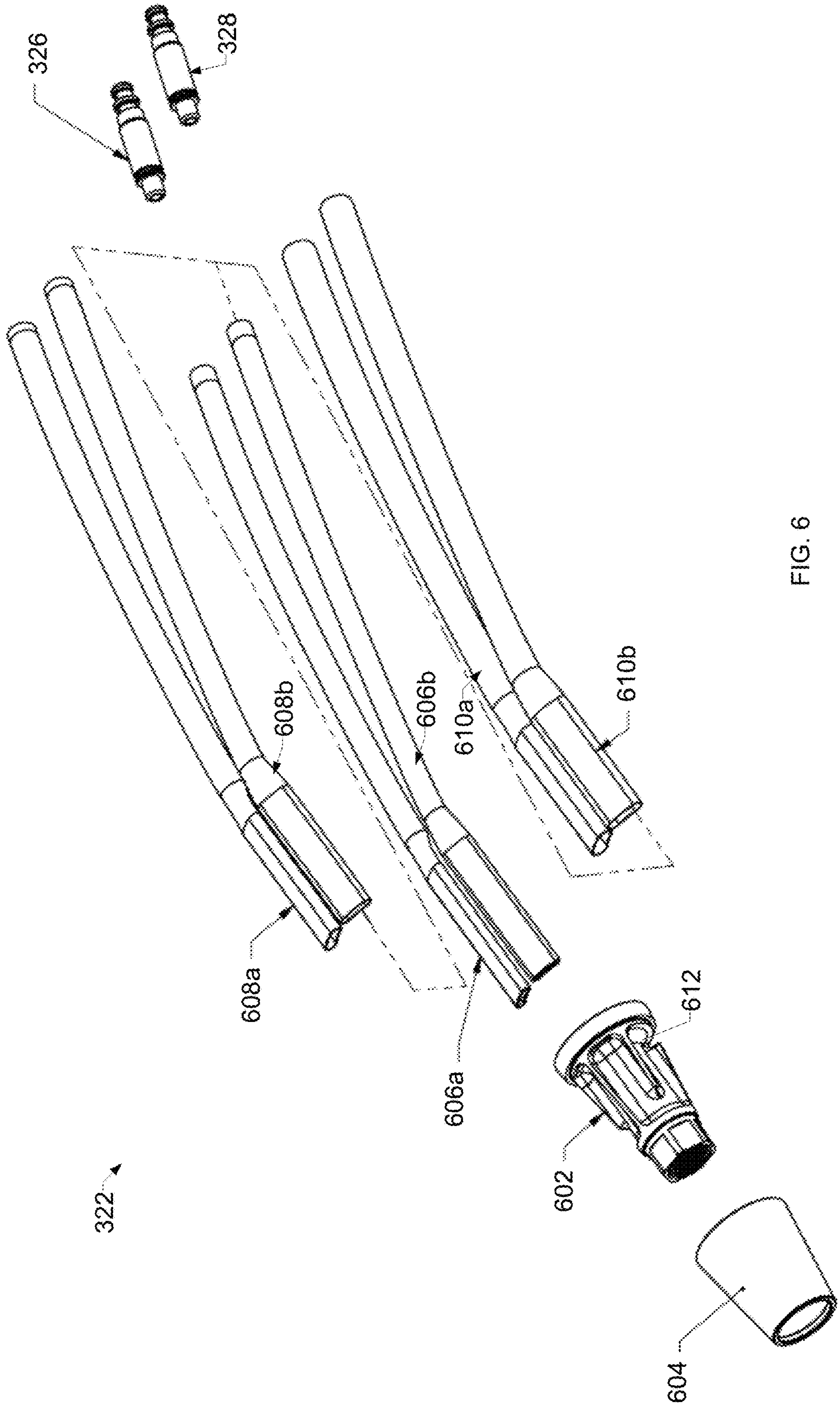


FIG. 6

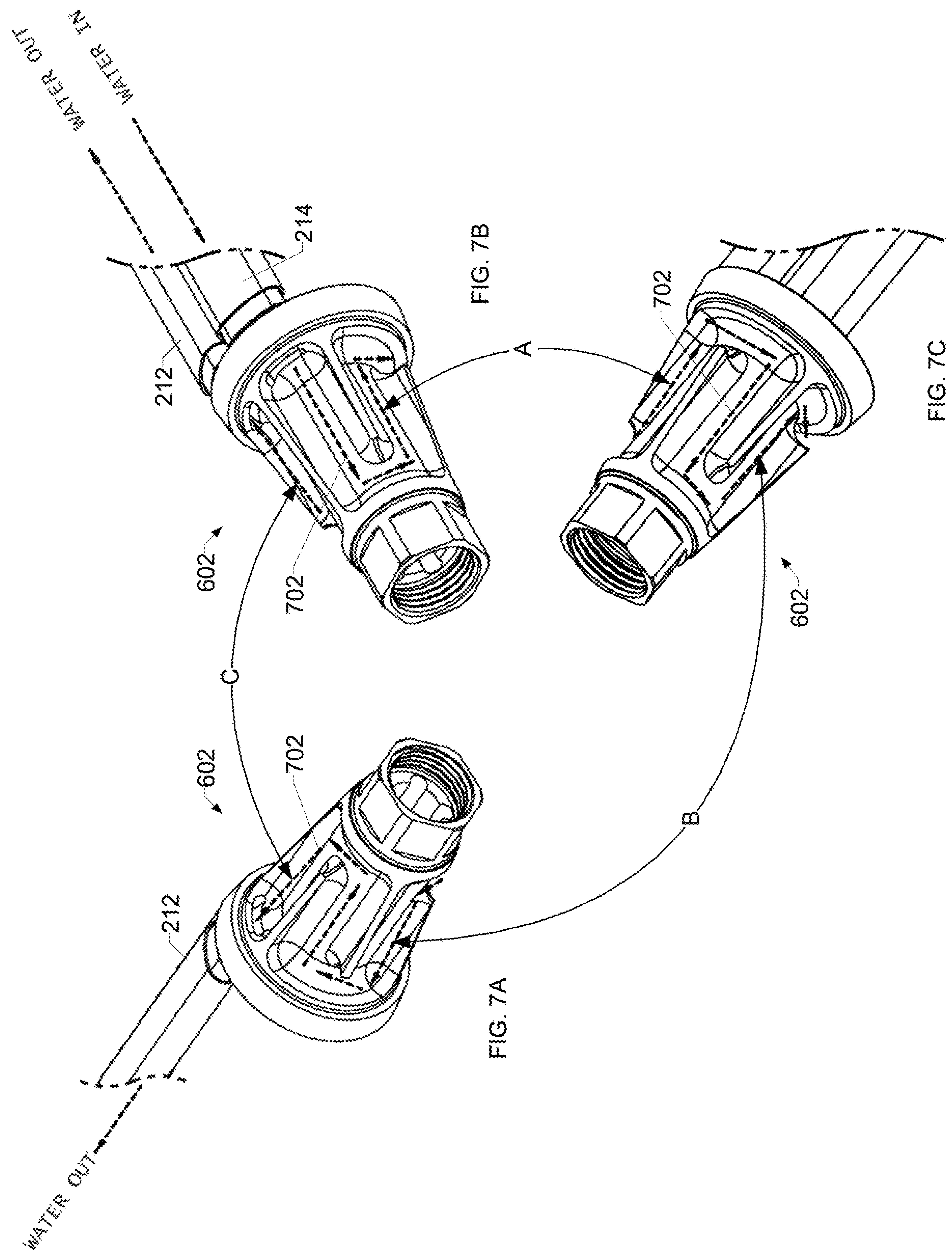


FIG. 7B

FIG. 7C

FIG. 7A

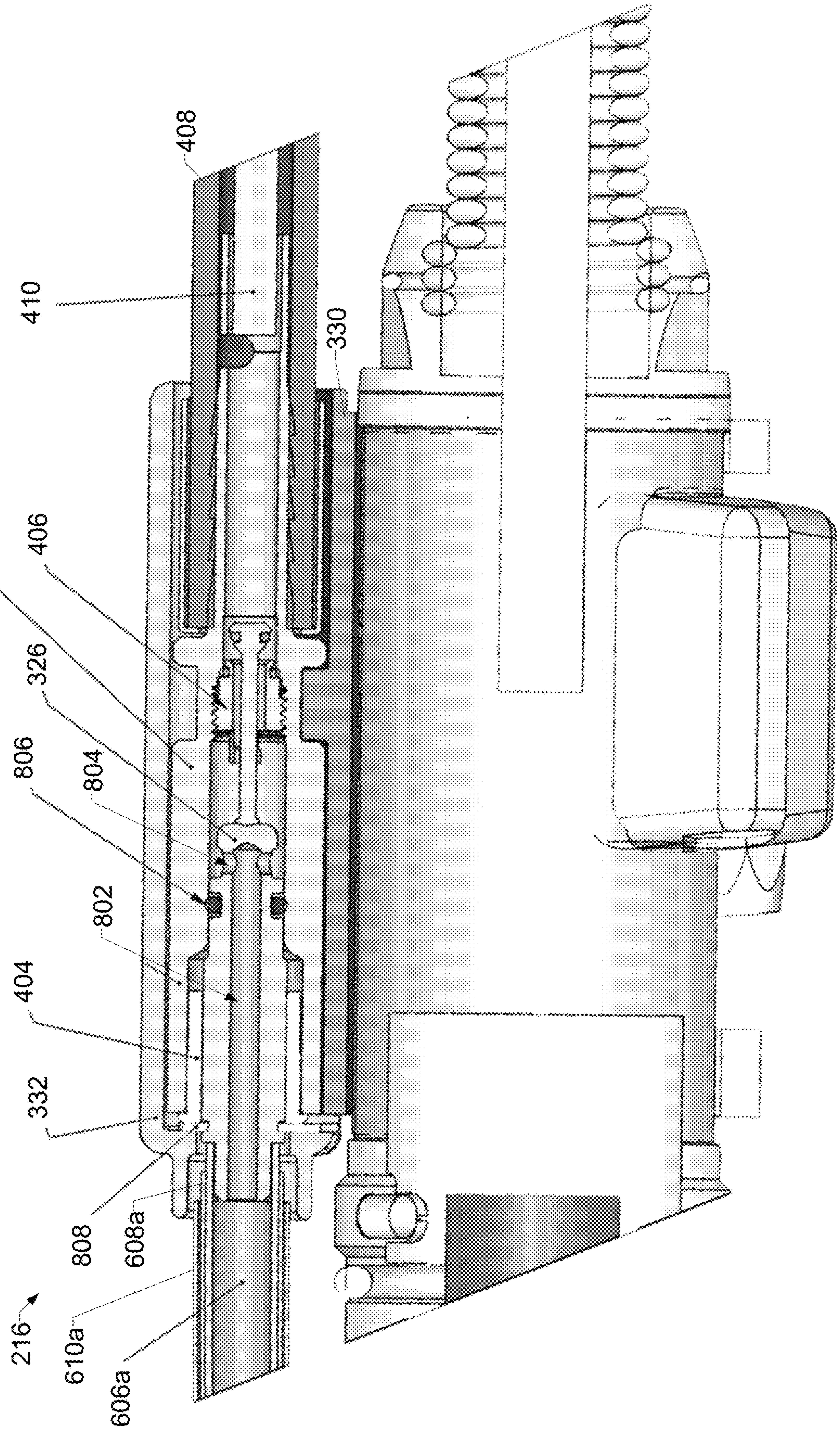

408
410
330
402
406
326
806
804
802
404
332
808
608a
216
610a
606a

FIG. 8

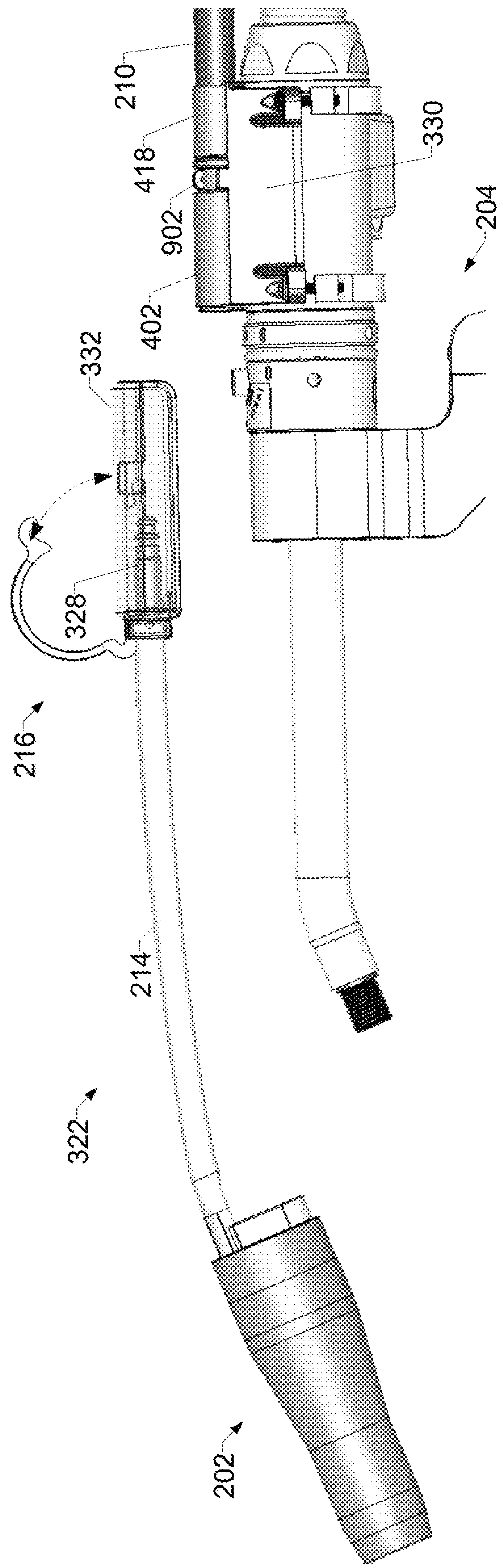


FIG. 9

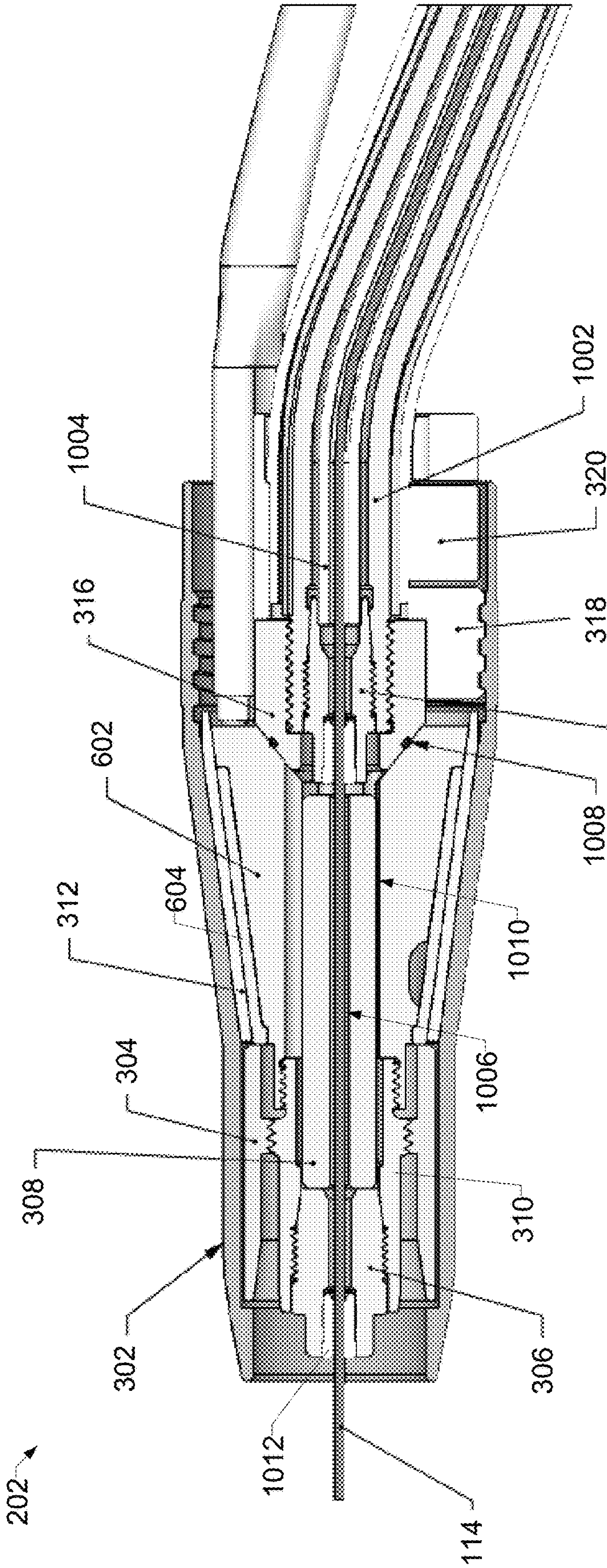

1002
1004
320
316
318
602
314
1008
604
1010
312
1006
304
308
310
302
306
1012
202
114

FIG. 10

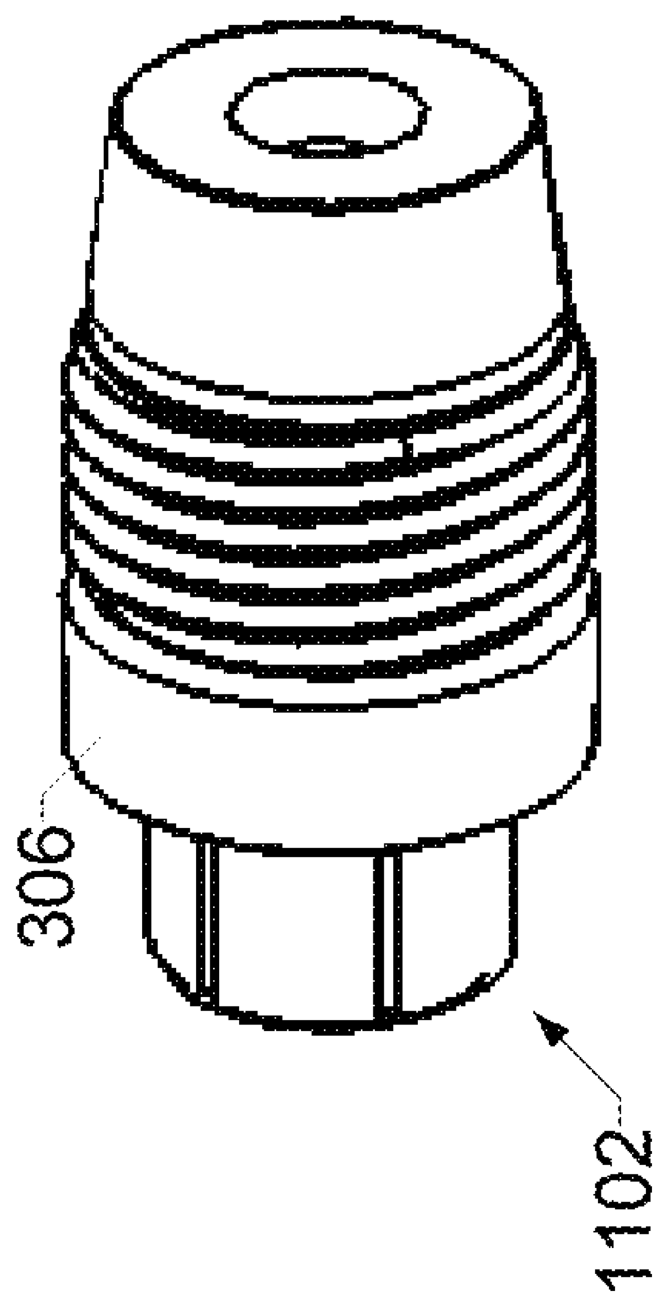


FIG. 11B

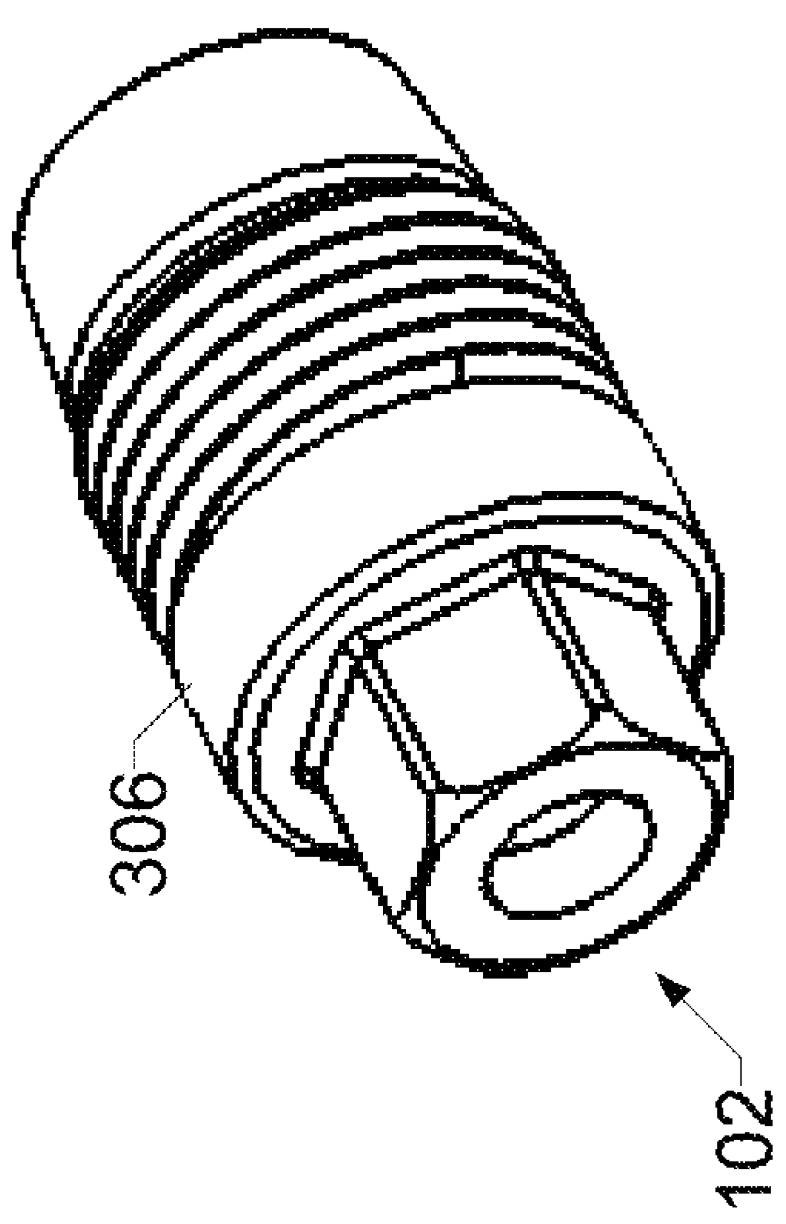


FIG. 11A

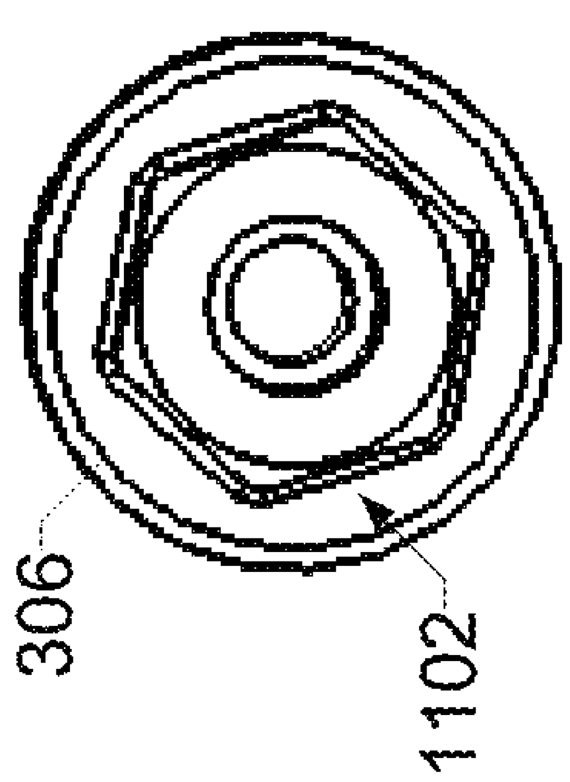


FIG. 11C

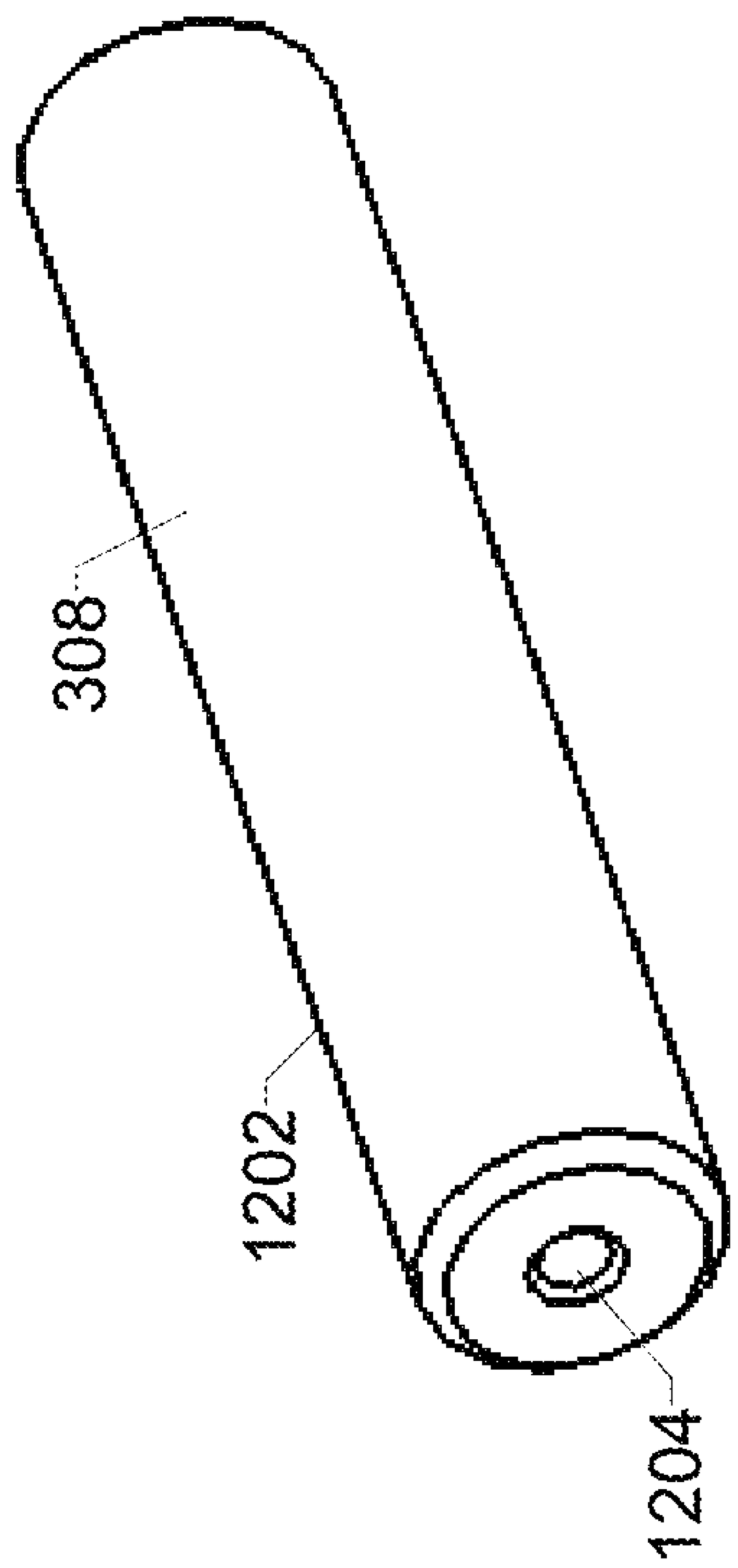


FIG. 12A

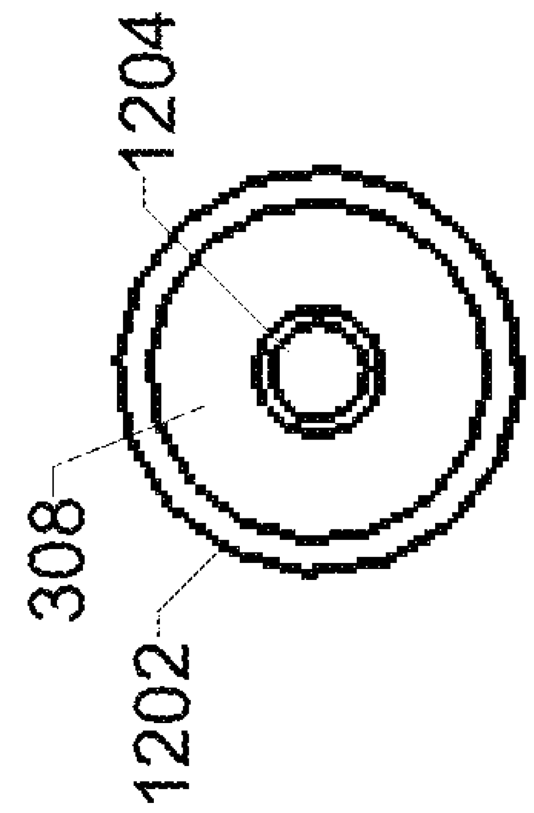


FIG. 12B

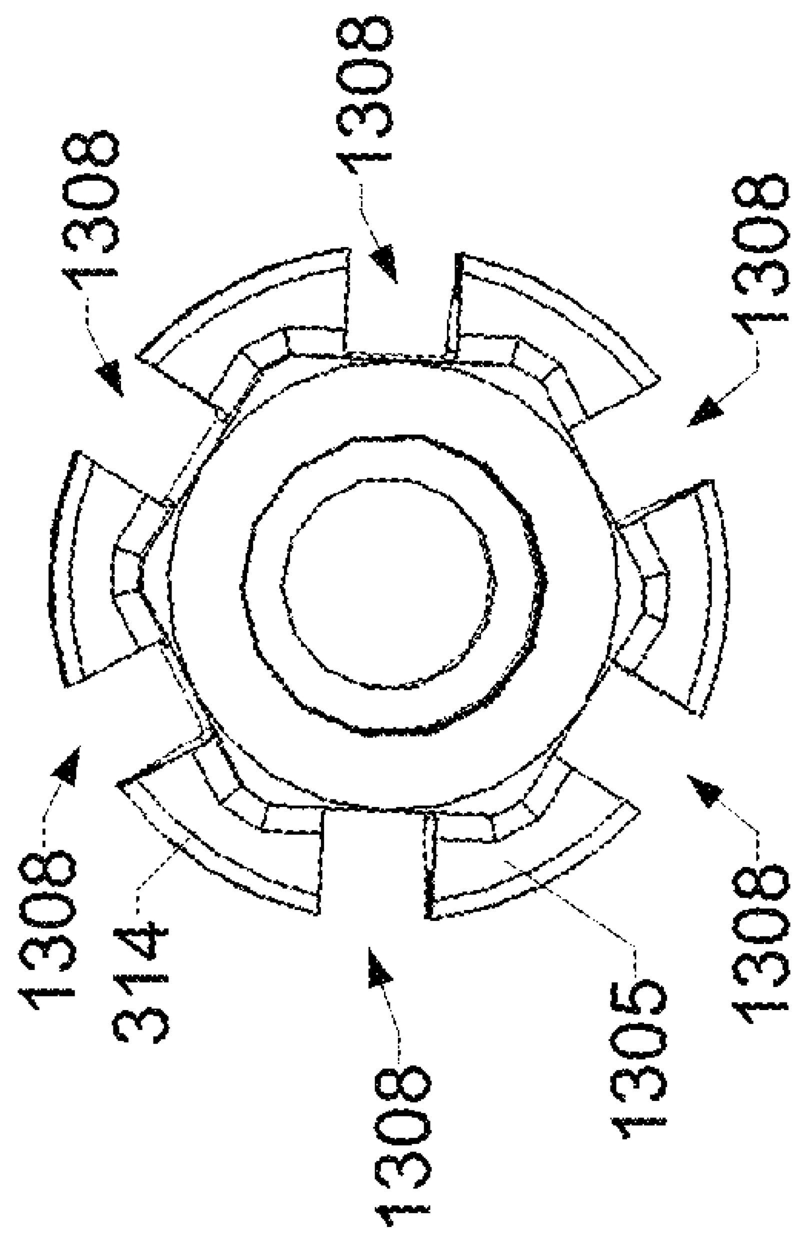


FIG. 13B

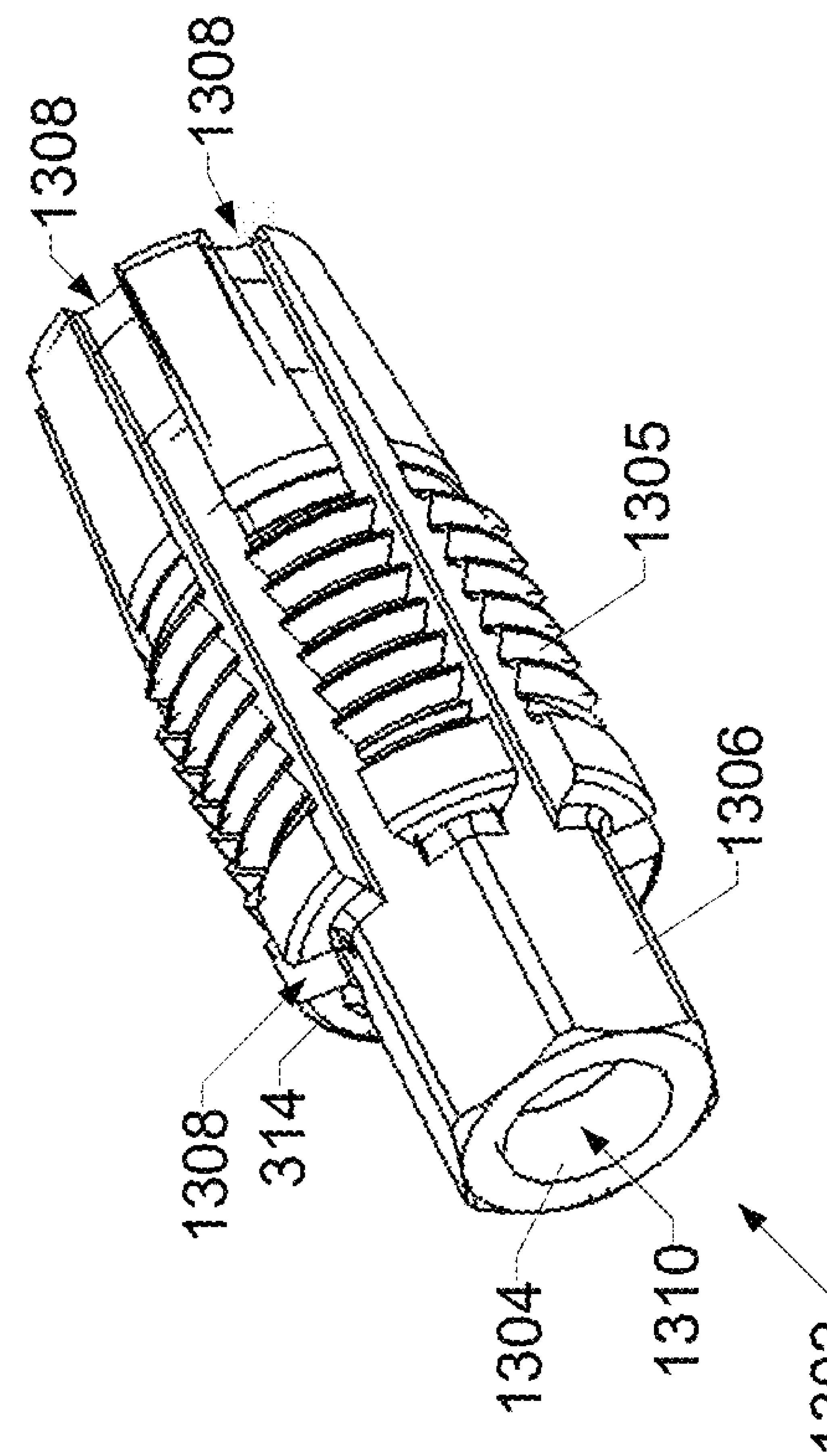


FIG. 13A

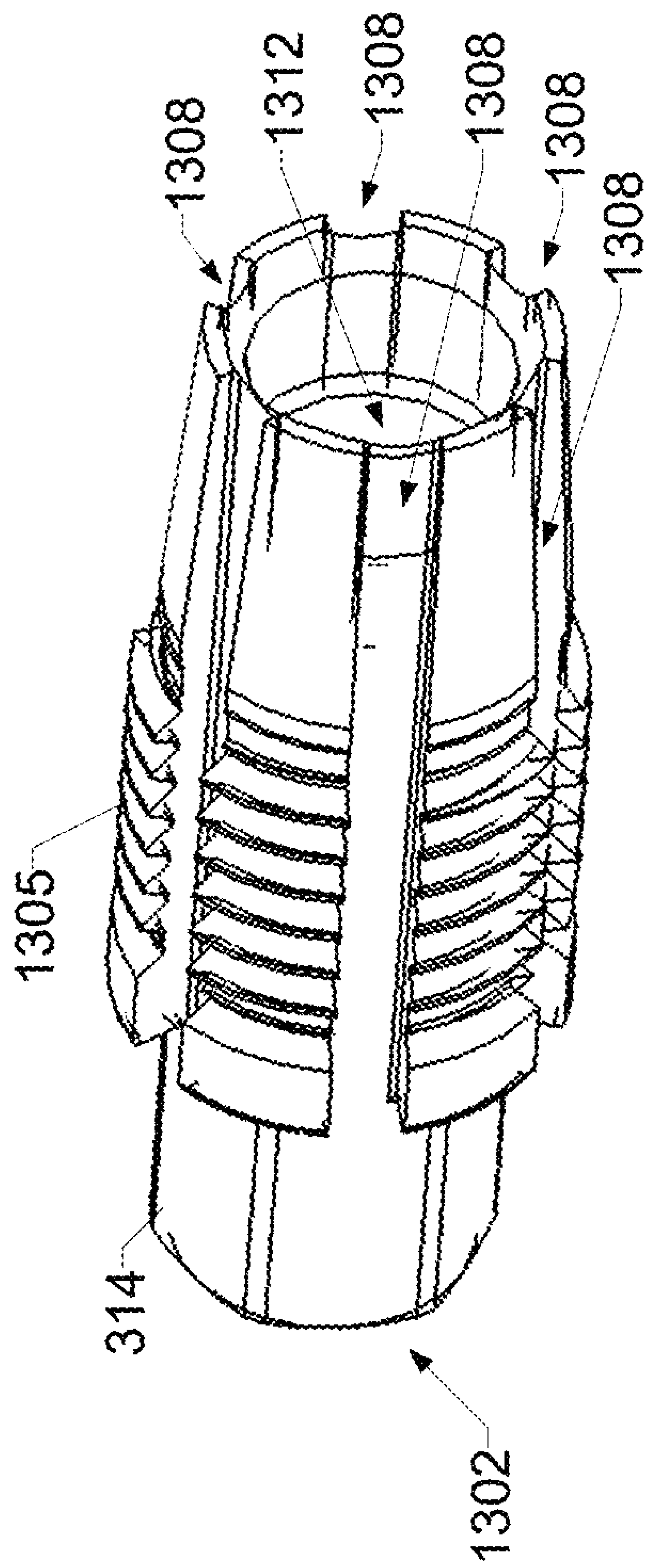


FIG. 13C

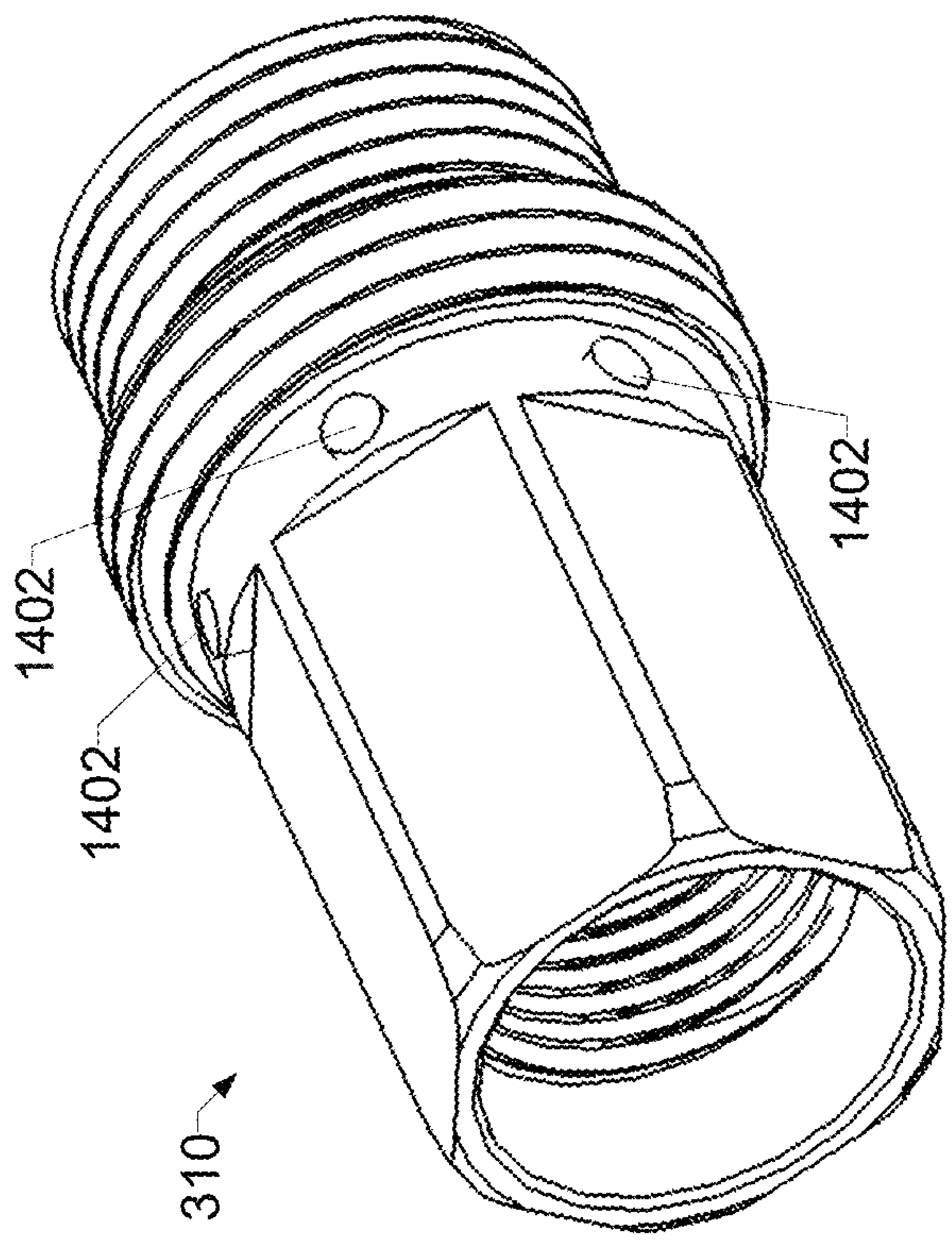


FIG. 14B

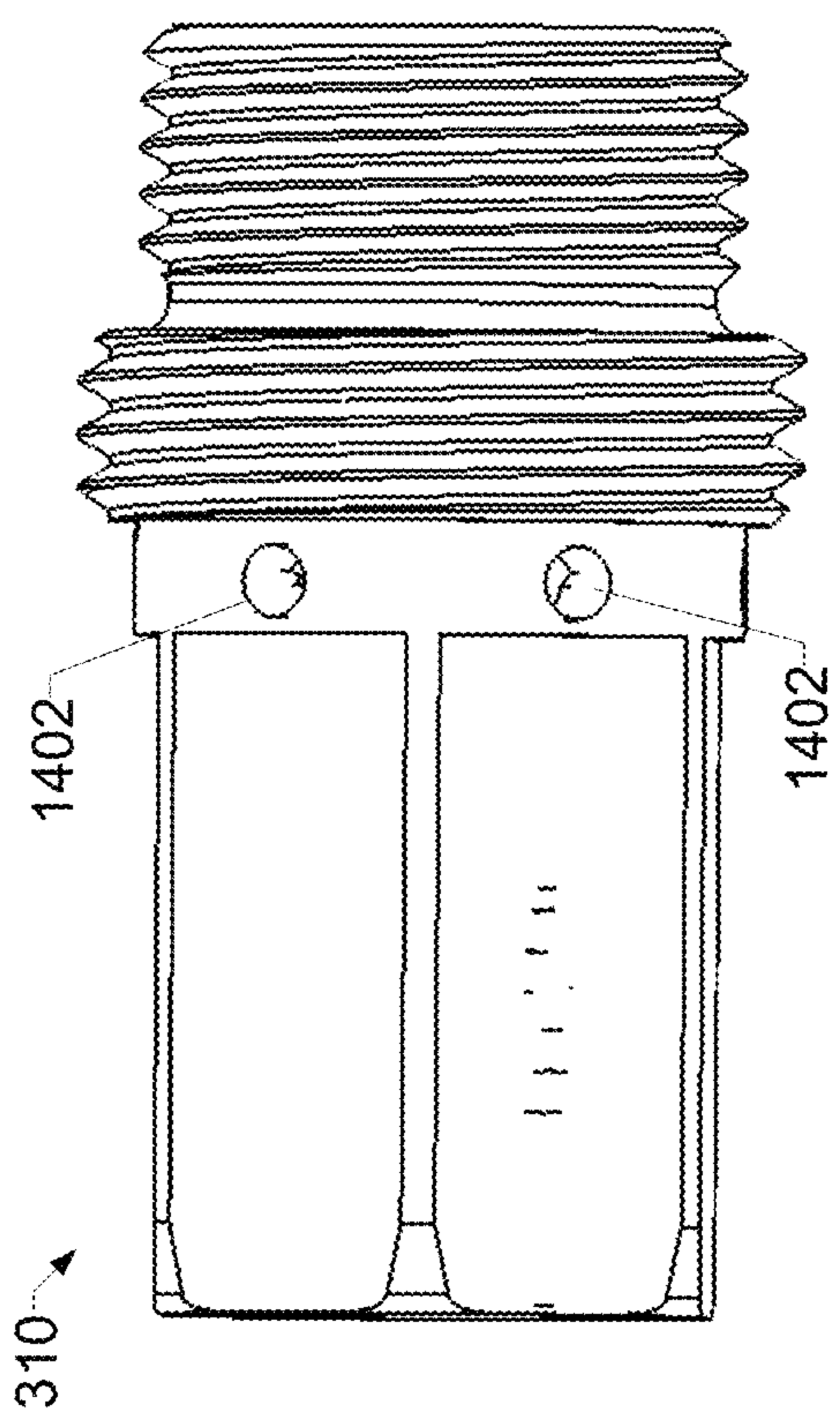


FIG. 14A

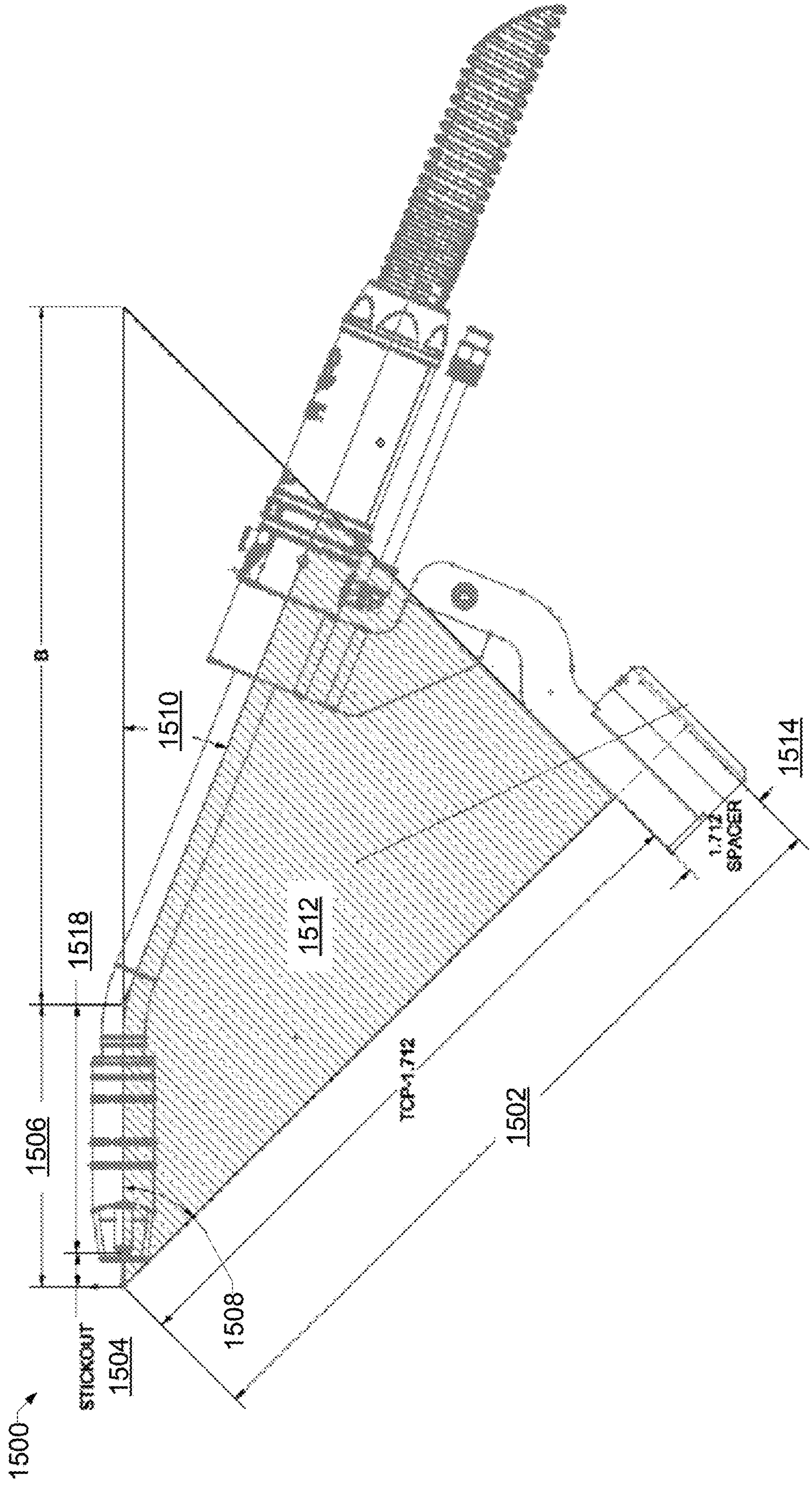

1500
STICKOUT
1504
1506
1508
1518
1510
B
1512
TCP-1.712
1502
1514
1.712
SPACER

FIG. 15A

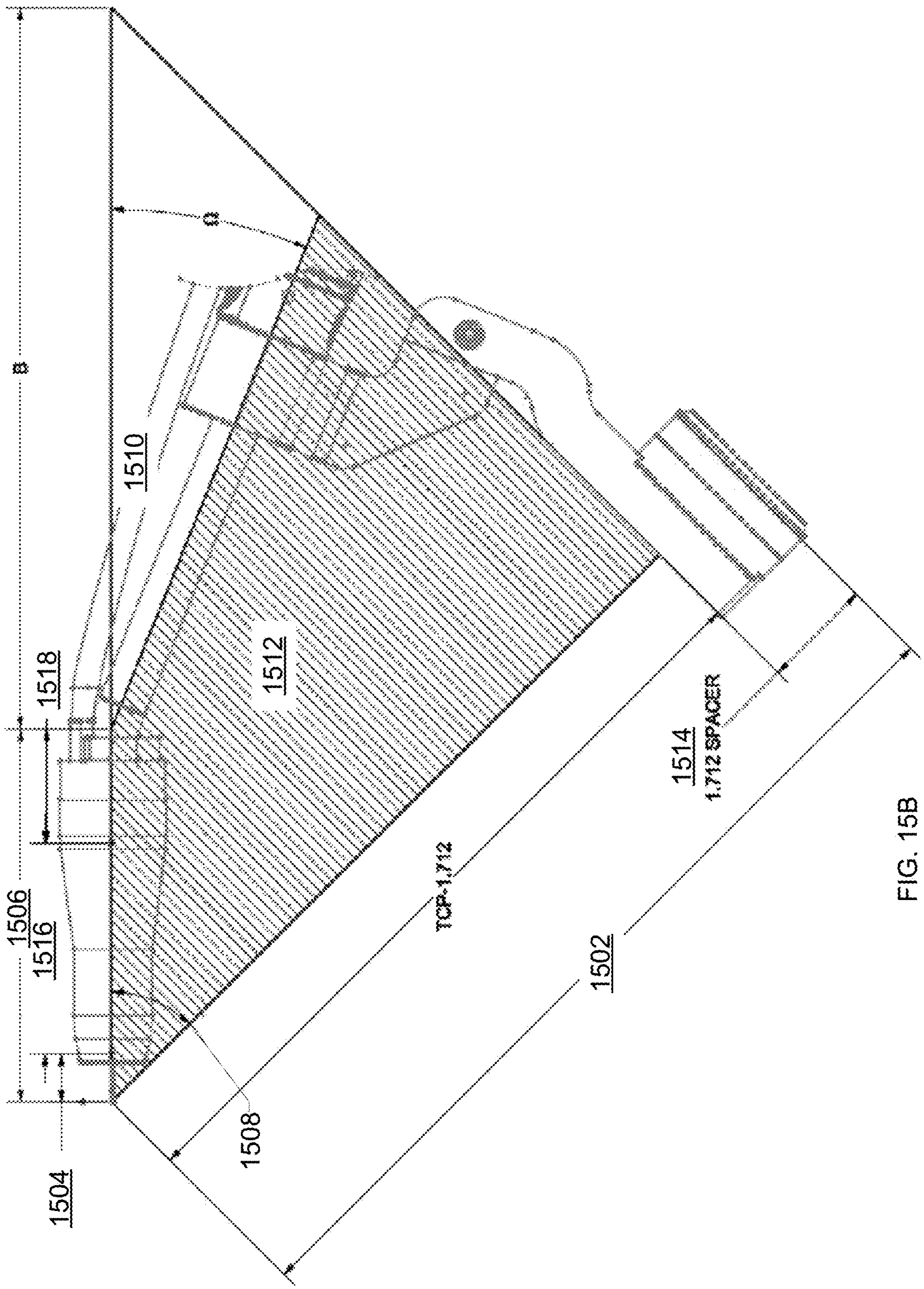

B
α
1510
1512
1518
1506
1516
1504
1508
1502
TCP-1.712
1514
1.712 SPACER

FIG. 15B

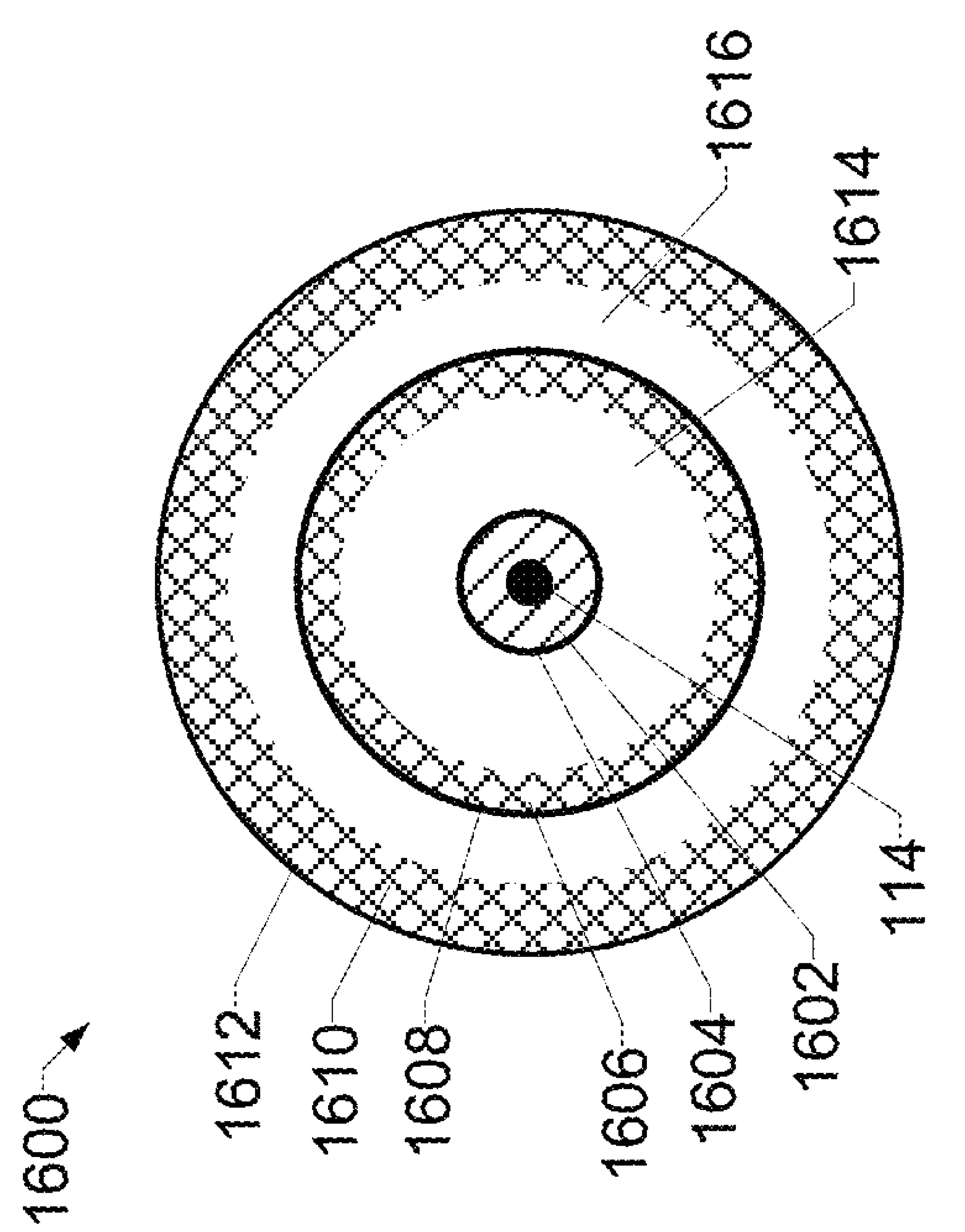


FIG. 16

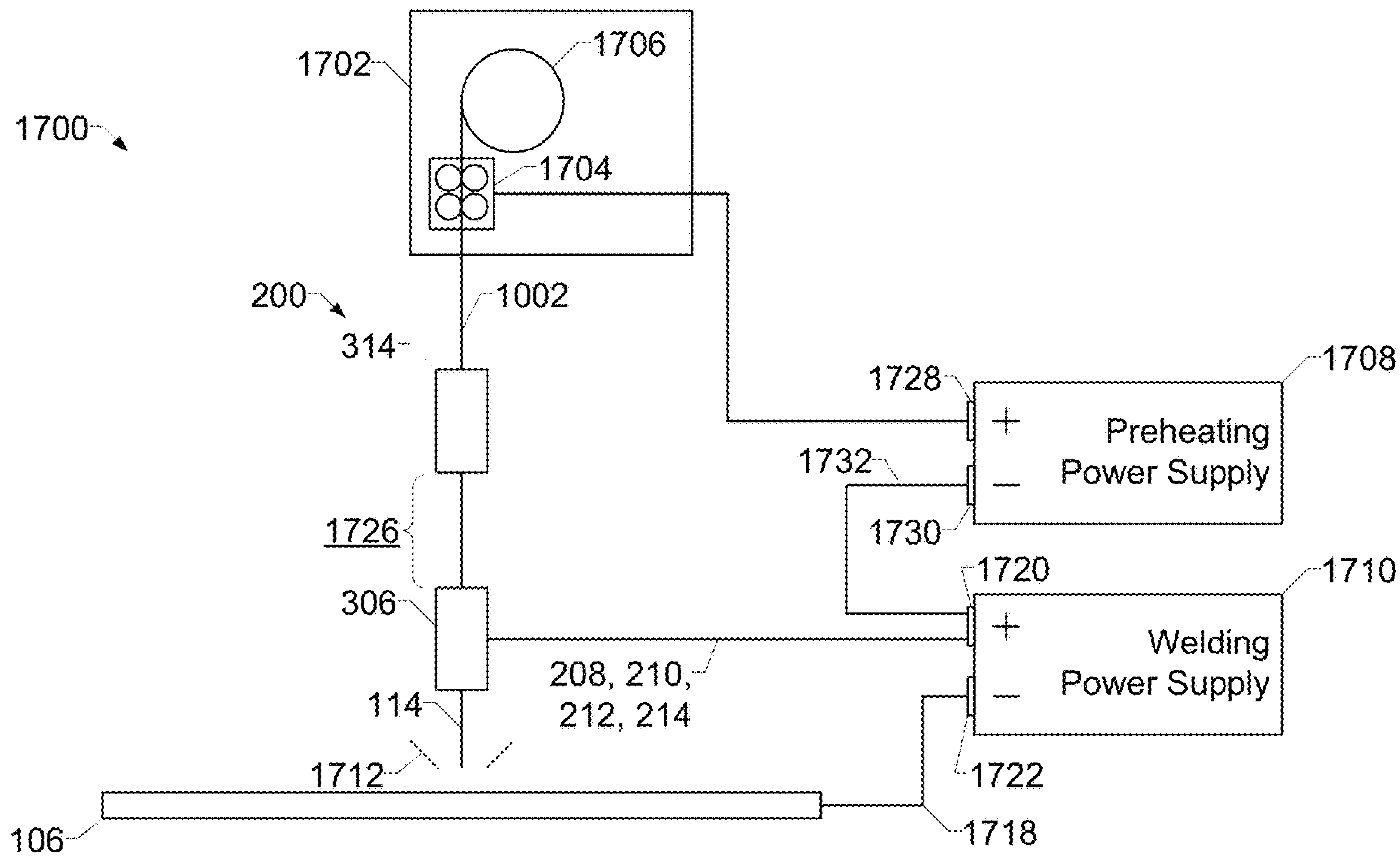

1702
1706
1700
1704
200
1002
314
1728
1708
Preheating
Power Supply
1732
1730
1726
1720
1710
306
Welding
Power Supply
208, 210,
212, 214
114
1712
1722
106
1718

FIG. 17

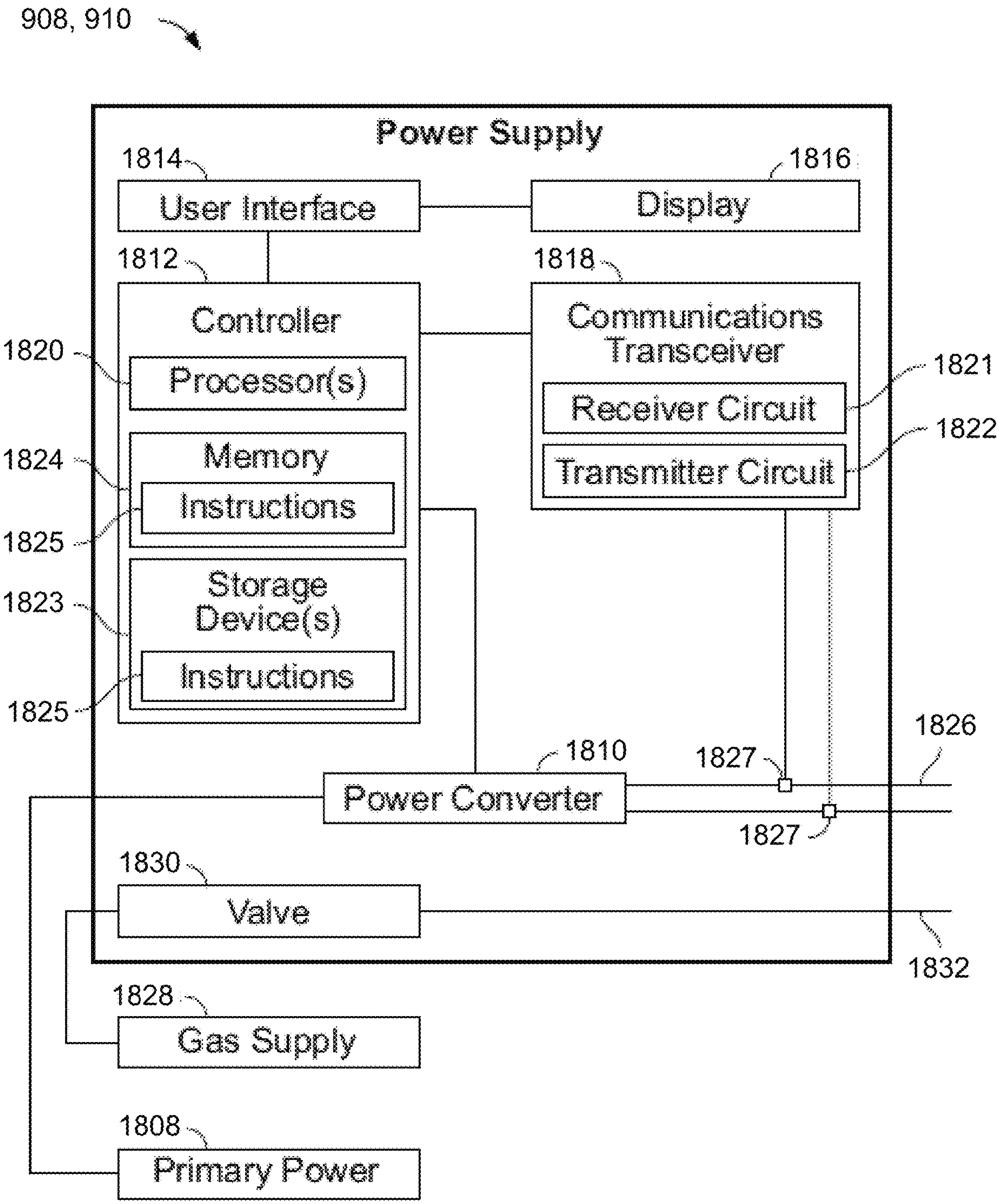

908, 910
Power Supply
1814
User Interface
1816
Display
1812
Controller
1818
Communications Transceiver
1820
Processor(s)
1821
Receiver Circuit
1822
Transmitter Circuit
1824
Memory
Instructions
1825
1823
Storage Device(s)
Instructions
1825
1826
1810
1827
Power Converter
1827
1830
Valve
1832
1828
Gas Supply
1808
Primary Power

FIG. 18

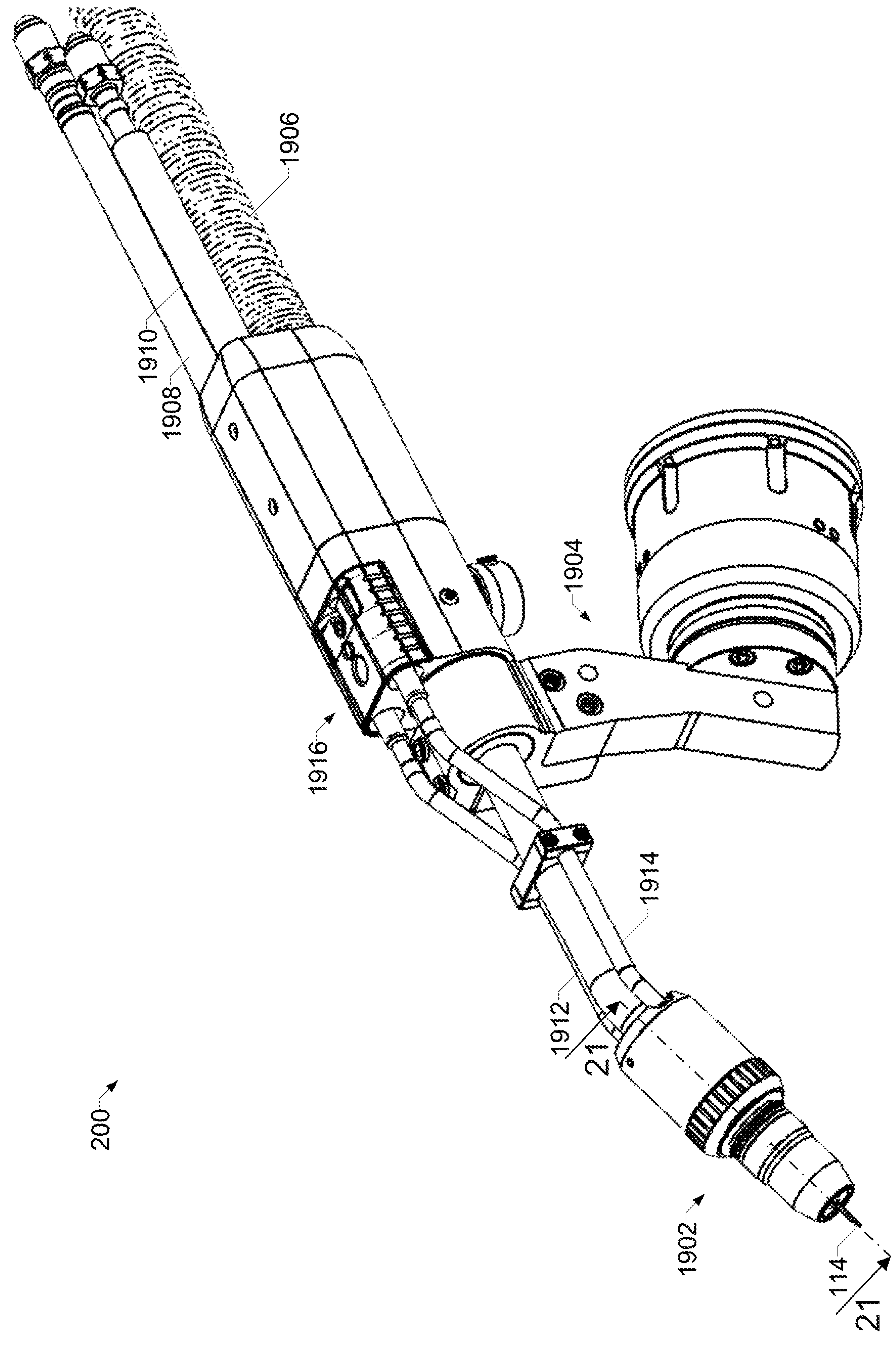
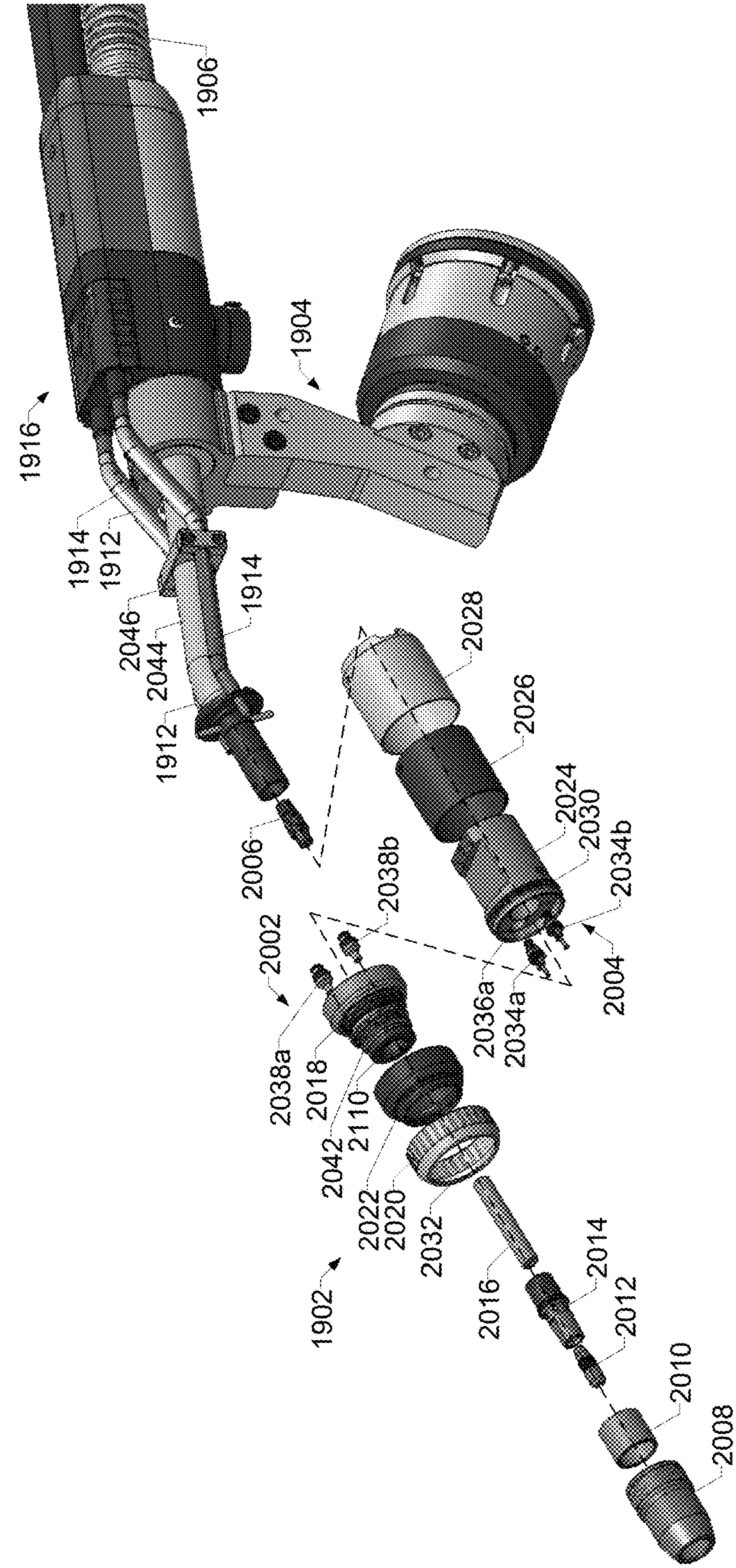


FIG. 19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1904
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2028
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2030
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2002
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2020
2032
1902
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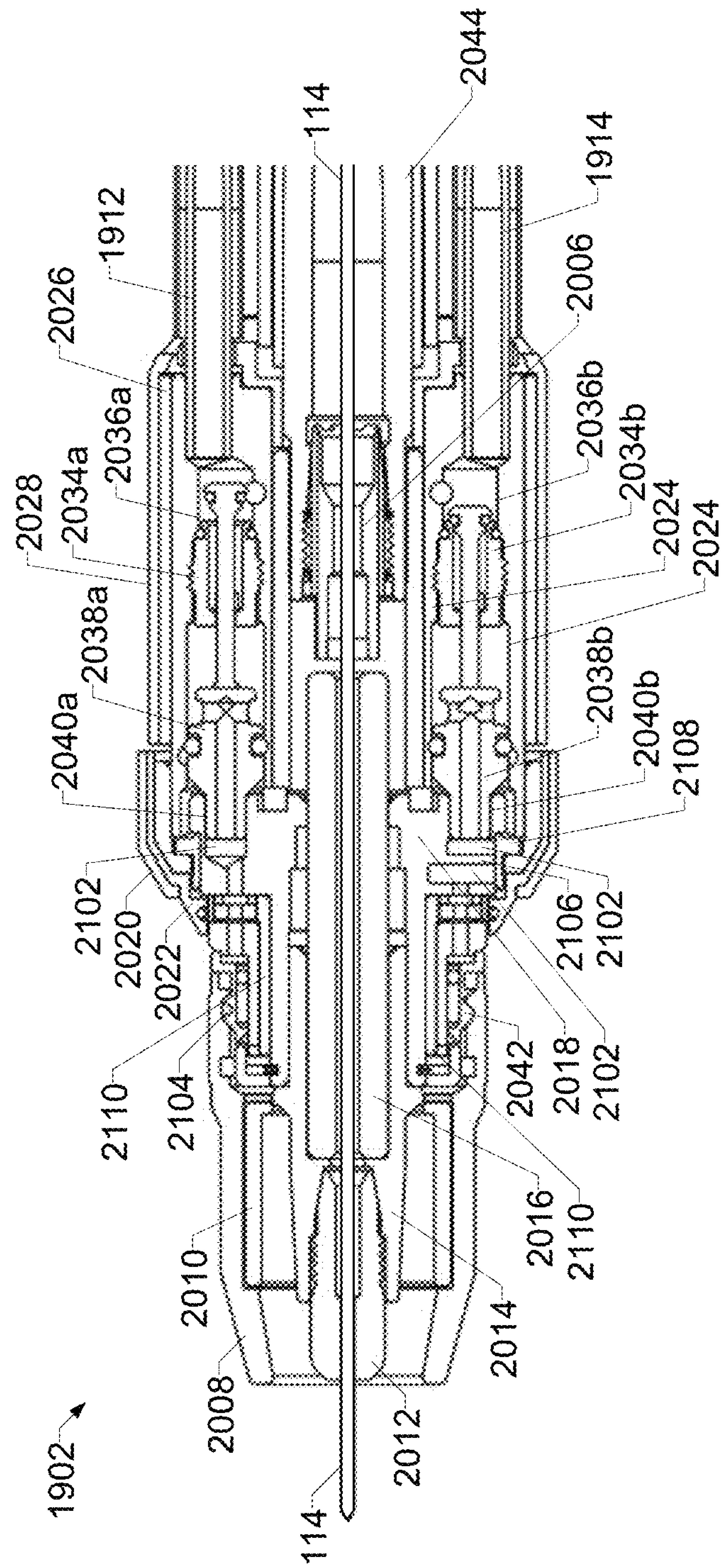
2012
2010
2008

FIG. 20



1902
114
2044
1914
1912
2006
2026
2036b
2036a
2034b
2034a
2024
2028
2024
2038a
2038b
2040a
2040b
2108
2102
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2102
2110
2104
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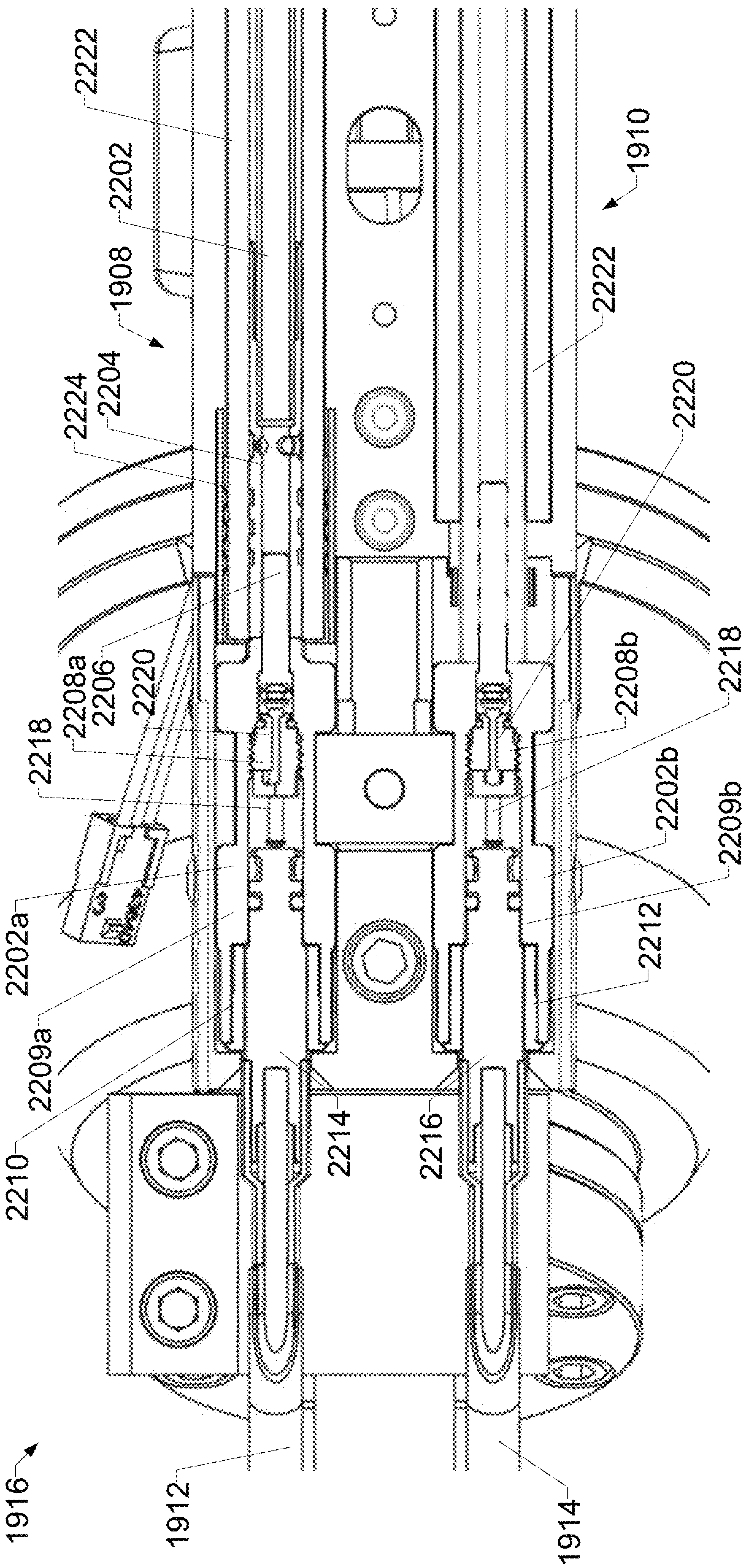
2018
2102
2010
2016
2110
2014
2008
2012
114

FIG. 21


2222
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2222
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2208a
2206
2220
2208b
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2202b
2209b
2202a
2212
2209a
2210
2214
2216
1916
1912
1914

FIG. 22

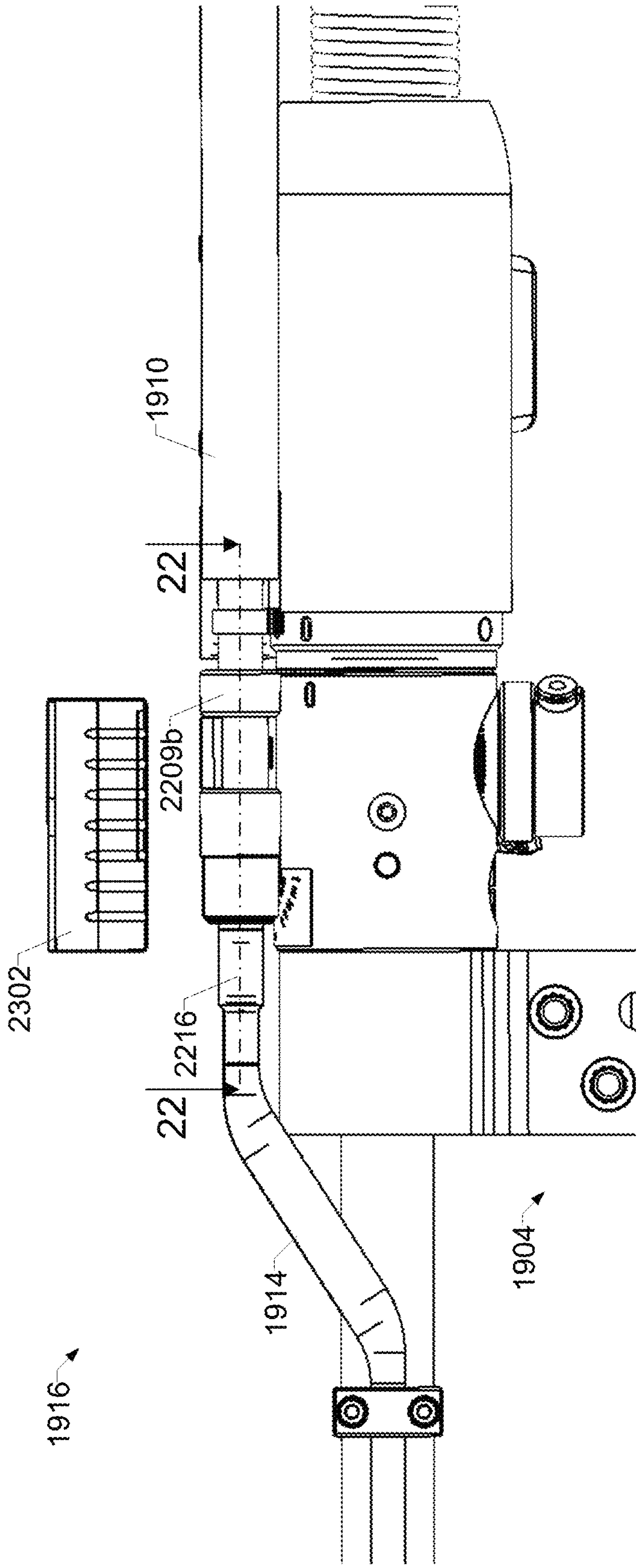

FIG. 23

SYSTEMS, METHODS, AND APPARATUS TO PREHEAT WELDING WIRE

RELATED APPLICATIONS

This patent claims priority to U.S. Provisional Patent Application Ser. No. 62/517,531, filed Jun. 9, 2007, entitled "Systems, Methods, and Apparatus to Preheat Welding Wire." The entirety of U.S. Provisional Patent Application Ser. No. 62/517,531 is incorporated herein by reference.

BACKGROUND

This disclosure relates generally to welding and, more particularly, to welding torches and methods to provide wire preheating for welding.

Welding is a process that has increasingly become ubiquitous in all industries. Welding is, at its core, simply a way of bonding two pieces of metal. A wide range of welding systems and welding control regimes have been implemented for various purposes. In continuous welding operations, metal inert gas (MIG) welding and submerged arc welding (SAW) techniques allow for formation of a continuing weld bead by feeding welding wire shielded by inert gas from a welding torch and/or by flux. Such wire feeding systems are available for other welding systems, such as tungsten inert gas (TIG) welding. Electrical power is applied to the welding wire and a circuit is completed through the workpiece to sustain a welding arc that melts the electrode wire and the workpiece to form the desired weld.

While very effective in many applications, these welding techniques may experience different initial welding performance based upon whether the weld is started with the electrode "cold" or "hot." In general, a cold electrode start may be considered a start in which the electrode tip and adjacent metals are at or relatively near the ambient temperature. Hot electrode starts, by contrast, are typically those in which the electrode tip and the adjacent metals' temperature are much more elevated, but below the melting point of the electrode wire. In some applications, it is believed that initiation of welding arcs and welds is facilitated when the electrode is hot. However, the current state of the art does not provide regimes designed to ensure that the electrode is heated prior to initiation of a welding operation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an example robotic welding system in which a robot is used to weld a workpiece using a welding tool, in accordance with aspects of this disclosure.

FIG. **2** illustrates an example liquid-cooled welding torch, in accordance with aspects of this disclosure.

FIG. **3** illustrates an exploded view of the example liquid-cooled welding torch of FIG. **2**.

FIG. **4** is a more detailed depiction of an example liquid cooling assembly that may be used to implement the liquid cooling assemblies of FIG. **2**.

FIG. **5** is a cross-section view of the liquid-cooled power cable assembly of FIG. **4**.

FIG. **6** is an exploded view of the example liquid-cooled power cable assembly of FIG. **3**.

FIGS. **7**A, **7**B, and **7**C are views of the example cooler body of FIG. **6**.

FIG. **8** is a cross-section view of the liquid cooling assembly and the quick-disconnect assembly of FIG. **2** coupled to the liquid cooling assembly of FIG. **4**.

FIG. **9** illustrates the example welding assembly and the example liquid cooling assemblies of FIG. **2** disconnected from the remainder of the torch via the quick-disconnect assembly.

FIG. **10** is a cross-section view of the example welding assembly of FIG. **2**.

FIGS. **11**A, **11**B, and **11**C show an example implementation of the first contact tip of FIG. **10**.

FIGS. **12**A and **12**B show an example implementation of the wire guide of FIG. **10**.

FIGS. **13**A, **13**B, and **13**C show an example implementation of the second contact tip of FIG. **10**.

FIGS. **14**A and **14**B illustrate views of the example diffuser of FIGS. **3** and **10**.

FIG. **15**A illustrates a conventional robotic welding torch having a first tool center point distance and torch neck angle, in accordance with aspects of this disclosure.

FIG. **15**B illustrates an example implementation of the liquid-cooled welding torch of FIG. **2** configured to replace the conventional torch of FIG. **15**A while maintaining a same tool center point distance and torch neck angle.

FIG. **16** is a cross section of an example welding cable that may be used to provide cooling liquid, welding current, and preheating current to a welding torch, and to carry cooling liquid away from the welding torch, in accordance with aspects of this disclosure.

FIG. **17** illustrates a functional diagram of an example welding system including the example welding torch of FIG. **2**, and which may be used with the welding system of FIG. **1**.

FIG. **18** is a block diagram of an example implementation of the power supplies of FIG. **17**.

FIG. **19** illustrates another example liquid-cooled welding torch, in accordance with aspects of this disclosure.

FIG. **20** is an exploded view of the example welding torch of FIG. **19**.

FIG. **21** is a cross-sectional plan view of the example welding assembly of FIG. **19**.

FIG. **22** is a cross-sectional plan view of the example power and liquid transfer assembly of FIG. **19**.

FIG. **23** is a view of the example power and liquid transfer assembly of FIG. **19**.

The figures are not to scale. Where appropriate, the same or similar reference numerals are used in the figures to refer to similar or identical elements.

DETAILED DESCRIPTION

For the purpose of promoting an understanding of the principles of this disclosure, reference will be now made to the examples illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the claims is intended by this disclosure. Modifications in the illustrated examples and such further applications of the principles of this disclosure as illustrated therein are contemplated as would typically occur to one skilled in the art to which this disclosure relates.

As used herein, the word "exemplary" means "serving as an example, instance, or illustration." The embodiments described herein are not limiting, but rather are exemplary only. It should be understood that the described embodiments are not necessarily to be construed as preferred or advantageous over other embodiments. Moreover, the terms "embodiments of the invention," "embodiments," or "invention" do not require that all embodiments of the invention include the discussed feature, advantage, or mode of operation.

As utilized herein the terms "circuits" and "circuitry" refer to physical electronic components (i.e. hardware) and any software and/or firmware (code) that may configure the hardware, be executed by the hardware, and or otherwise be associated with the hardware. As used herein, for example, a particular processor and memory may comprise a first "circuit" when executing a first set of one or more lines of code and may comprise a second "circuit" when executing a second set of one or more lines of code. As utilized herein, "and/or" means any one or more of the items in the list joined by "and/or". As an example, "x and/or y" means any element of the three-element set {(x), (y), (x, y)}. In other words, "x and/or y" means "one or both of x and y." As another example, "x, y, and/or z" means any element of the seven-element set {(x), (y), (z), (x, y), (x, z), (y, z), (x, y, z)}. In other words, "x, y, and/or z" means "one or more of x, y and z". As utilized herein, the term "exemplary" means serving as a non-limiting example, instance, or illustration. As utilized herein, the terms "e.g." and "for example" set off lists of one or more non-limiting examples, instances, or illustrations. As utilized herein, circuitry is "operable" to perform a function whenever the circuitry comprises the necessary hardware and code (if any is necessary) to perform the function, regardless of whether performance of the function is disabled or not enabled (e.g., by an operator-configurable setting, factory trim, etc.).

As used herein, a wire-fed welding-type system refers to a system capable of performing welding (e.g., gas metal arc welding (GMAW), gas tungsten arc welding (GTAW), etc.), brazing, cladding, hardfacing, and/or other processes, in which a filler metal is provided by a wire that is fed to a work location, such as an arc or weld puddle.

As used herein, a welding-type power source refers to any device capable of, when power is applied thereto, supplying welding, cladding, plasma cutting, induction heating, laser (including laser welding and laser cladding), carbon arc cutting or gouging and/or resistive preheating, including but not limited to transformer-rectifiers, inverters, converters, resonant power supplies, quasi-resonant power supplies, switch-mode power supplies, etc., as well as control circuitry and other ancillary circuitry associated therewith.

As used herein, preheating refers to heating the electrode wire prior to a welding arc and/or deposition in the travel path of the electrode wire.

As used herein, the terms "front" and/or "forward" refer to locations closer to a welding arc, while "rear," "back," "behind," and/or "backward" refers to locations farther from a welding arc.

Some disclosed examples describe electric currents being conducted "from" and/or "to" locations in circuits and/or power supplies. Similarly, some disclosed examples describe "providing" electric current via one or more paths, which may include one or more conductive or partially conductive elements. The terms "from," "to," and "providing," as used to describe conduction of electric current, do not necessitate the direction or polarity of the current. Instead, these electric currents may be conducted in either direction or have either polarity for a given circuit, even if an example current polarity or direction is provided or illustrated.

Disclosed example welding torches include: a first contact tip configured to conduct welding current to a consumable electrode; a second contact tip configured to conduct preheating current to the consumable electrode; and a plurality of liquid cooling assemblies configured to conduct the preheating current and to conduct the welding current to the consumable electrode.

In some examples, the plurality of liquid cooling assemblies includes: a first liquid cooling assembly configured to conduct the welding current; and a second liquid cooling assembly configured to conduct the preheating current. In some examples, the first liquid cooling assembly is configured to conduct the preheating current. Some example welding torches further include: a first socket having a first fluid valve and configured to permit fluid transfer with a first one of the liquid cooling assemblies when the first fluid valve is open; and a second socket electrically coupled to the first socket, wherein the first one of the liquid cooling assemblies comprises a first power connector pin configured to be inserted into the first socket and the second socket to transfer the fluid and to be electrically coupled to the second socket, the first fluid valve configured to open when the first power connector pin is inserted into the first socket and to close when the first power connector pin is removed from the first socket.

Some example welding torches further include a power connector pin retention mechanism configured to physically resist removal of the first power connector pin from the first socket and the second socket when engaged. Some example welding torches further include a retaining ring configured to attach the power connector pin retention mechanism to the first power connector pin. Some example welding torches further include a third socket having a second fluid valve and configured to permit fluid transfer with a second one of the liquid cooling assemblies when the second fluid valve is open. In some examples, the second socket includes a plurality of contacts arranged circumferentially around an interior surface of the second socket, the plurality of contacts configured to contact the first power connector pin to transfer at least one of the welding current or the preheating current.

In some examples, the plurality of liquid cooling assemblies include a first liquid cooling assembly configured to conduct the welding current and to provide a return path for the preheating current; and a second liquid cooling assembly. Some example welding torches further include a welding assembly having the first contact tip and the second contact tip, in which the welding assembly fluidly is coupled to the plurality of liquid cooling assemblies. In some examples, a first one of the liquid cooling assemblies includes an inner conductive layer configured to conduct at least one of the welding current or the preheating current; and an insulative layer exterior to the inner conductive layer. In some examples, the first one of the liquid cooling assemblies further includes an outer protective layer exterior to the insulative layer.

Some example welding torches further include a power and liquid transfer assembly configured to be fluidly and electrically coupled to the plurality of liquid cooling assemblies and, when fluidly and electrically coupled to the plurality of liquid cooling assemblies, to transfer current and coolant with the plurality of liquid cooling assemblies. Some example welding torches further include a securing mechanism configured to secure the power and liquid transfer assembly to the plurality of liquid cooling assemblies.

Some example welding torches further include a torch neck configured to detachably attach a welding assembly to a torch body, in which the welding assembly includes the first contact tip and the second contact tip, and the plurality of liquid cooling assemblies are mechanically coupled to the torch neck. In some examples, the power and liquid transfer assembly is mechanically coupled to the torch body.

Some example welding torches further include a weld cable configured to conduct the preheating current, welding gas, and the consumable electrode to the welding torch. In some examples, the weld cable is an air-cooled or gas-cooled cable.

Referring to FIG. **1**, an example welding system **100** is shown in which a robot **102** is used to weld a workpiece **106** using a welding tool **108**, such as the illustrated bent-neck (i.e., gooseneck design) welding torch (or, when under manual control, a handheld torch), to which power is delivered by welding equipment **110** via conduit **118** and returned by way of a ground conduit **120**. The welding equipment **110** may comprise, inter alia, one or more power sources (each generally referred to herein as a "power supply"), a source of a shield gas, a wire feeder, and other devices. Other devices may include, for example, water coolers, fume extraction devices, one or more controllers, sensors, user interfaces, communication devices (wired and/or wireless), etc.

The welding system **100** of FIG. **1** may form a weld (e.g., at weld joint **112**) between two components in a weldment by any known electric welding techniques. Known electric welding techniques include, inter alia, shielded metal arc welding (SMAW), MIG, flux-cored arc welding (FCAW), TIG, laser welding, sub-arc welding (SAW), stud welding, friction stir welding, and resistance welding. MIG, TIG, hot wire cladding, hot wire TIG, hot wire brazing, multiple arc applications, and SAW welding techniques, inter alia, may involve automated or semi-automated external metal filler (e.g., via a wire feeder). In multiple arc applications (e.g., open arc or sub-arc), the preheater may pre-heat the wire into a pool with an arc between the wire and the pool. The welding equipment **110** may be arc welding equipment having one or more power supplies, and associated circuitry, that provides a direct current (DC), alternating current (AC), or a combination thereof to an electrode wire **114** of a welding tool (e.g., welding tool **108**). The welding tool **108** may be, for example, a TIG torch, a MIG torch, or a flux cored torch (commonly called a MIG "gun"). The electrode wire **114** may be tubular-type electrode, a solid type wire, a flux-core wire, a seamless metal core wire, and/or any other type of electrode wire.

As will be discussed below, the welding tool **108** employs a contact tip assembly that heats the electrode wire **114** prior to forming a welding arc using the electrode wire **114**. Suitable electrode wire **114** types includes, for example, tubular wire, metal cored wire, aluminum wire, solid gas metal arc welding (GMAW) wire, composite GMAW wire, gas-shielded FCAW wire, SAW wire, self-shielded wire, etc.

In the welding system **100**, the robot **102**, which is operatively coupled to welding equipment **110** via conduit **118** and ground conduit **120**, controls the location of the welding tool **108** and operation of the electrode wire **114** (e.g., via a wire feeder) by manipulating the welding tool **108** and triggering the starting and stopping of the current flow (whether a preheat current and/or welding current) to the electrode wire **114** by sending, for example, a trigger signal to the welding equipment **110**. When welding current is flowing, a welding arc is developed between the electrode wire **114** and the workpiece **106**, which ultimately produces a weldment. The conduit **118** and the electrode wire **114** thus deliver welding current and voltage sufficient to create the electric welding arc between the electrode wire **114** and the workpiece **106**. At the point of welding between the electrode wire **114** and the workpiece **106**, the welding arc locally melts the workpiece **106** and electrode wire **114** supplied to the weld joint **112**, thereby forming a weld joint **112** when the metal cools.

In certain aspects, in lieu of a robot **102**'s robotic arm, a human operator may control the location and operation of the electrode wire **114**. For example, an operator wearing welding headwear and welding a workpiece **106** using a handheld torch to which power is delivered by welding equipment **110** via conduit **118**. In operation, as with the system **100** of FIG. **1**, an electrode wire **114** delivers the current to the point of welding on the workpiece **106** (e.g., a weldment). The operator, however, could control the location and operation of the electrode wire **114** by manipulating the handheld torch and triggering the starting and stopping of the current flow via, for example, a trigger. A handheld torch generally comprises a handle, a trigger, a conductor tube, a nozzle at the distal end of the conductor tube, and a contact tip assembly. Applying pressure to the trigger (i.e., actuating the trigger) initiates the welding process by sending a trigger signal to the welding equipment **110**, whereby welding current is provided, and the wire feeder is activated as needed (e.g., to drive the electrode wire **114** forward to feed the electrode wire **114** and in reverse to retract the electrode wire **114**). Commonly owned U.S. Pat. No. 6,858,818 to Craig S. Knoener, for example, describes an example system and method of controlling a wire feeder of a welding-type system.

FIG. **2** illustrates an example liquid-cooled welding torch **200**. The liquid-cooled welding torch **200** may be used to implement the welding tool **108** of FIG. **1** to deliver the electrode wire **114** to a workpiece while providing both resistive preheating power and welding-type power.

The liquid-cooled welding torch **200** includes a welding assembly **202**, a mounting assembly **204**, a weld cable **206**, liquid cooling assemblies **208**, **210**, **212**, **214**, and a power and liquid transfer assembly **216**. As disclosed herein, the example liquid-cooled welding torch **200** may be used to replace conventional robotic welding torches with resistive preheating-enabled welding torches having a same tool center point (TCP). By replacing a torch with another torch having a same TCP, the robot may be capable of continuing a welding program using the replacement torch with little or no reprogramming of tool points.

The welding assembly **202** receives weld current and preheating current, conducts the weld current to the electrode wire **114**, and conducts the preheating current through a portion of the electrode wire **114**. The example welding assembly **202** is liquid-cooled by liquid provided via the liquid cooling assemblies **208-214**. The example welding assembly **202** of FIG. **2** receives the weld current via one or more of the weld cable **206**, the liquid cooling assemblies **208** and **212**, and/or the liquid cooling assemblies **210** and **214**. Because the workpiece provides the return path for the weld current to the power supply, no return path is provided via the weld cable **206** or the liquid cooling assemblies **208**. The weld cable **206** is an air-cooled (or gas-cooled) cable. However, the weld cable **206** may also be liquid-cooled.

The example welding assembly **202** receives the preheating current via the weld cable **206**, the liquid cooling assemblies **208** and **212**, and/or the liquid cooling assemblies **210** and **214**. In the example of FIG. **2**, the weld current is conducted via a different one of the weld cable **206**, the liquid cooling assemblies **208** and **212**, or the liquid cooling assemblies **210** and **214** than the preheating current that has the same polarity (i.e., current flow direction). The welding assembly **202** conducts the preheating current through a section of the electrode wire **114** to heat the electrode wire via resistive heating (e.g., I^2R heating). The preheat current then returns to a preheating power supply via a different one of weld cable **206**, the liquid cooling assemblies **208** and **212**, or the liquid cooling assemblies **210** and **214** to complete a preheating circuit.

In the example of FIG. **2**, the weld current path, the preheating current supply path, and the preheating current return path may all be different ones of the weld cable **206**, the liquid cooling assemblies **208** and **212**, and the liquid cooling assemblies **210** and **214**. In some examples, the weld current path may be superimposed with the preheating current supply path or the preheating current return path to reduce the net current in the conductor. For example, if the weld current is 300 A and the preheating current is 100 A, the weld current and the preheating current may be superimposed to result in a net current of 200 A.

As described in more detail below, the welding assembly **202** and the liquid cooling assemblies **212**, **214** may be separated from the remainder of the liquid-cooled welding torch **200** via the power and liquid transfer assembly **216**.

FIG. **3** illustrates an exploded view of the example liquid-cooled welding torch **200** of FIG. **2**.

As shown in FIG. **3**, the example welding assembly **202** includes a nozzle **302**, a diffuser insulator **304**, a first contact tip **306**, a wire guide **308**, a gas diffuser **310**, a first contact tip insulator **312**, a second contact tip **314**, a second contact tip insulator **316**, a nozzle mount **318**, and a nozzle mount clamp **320**.

A liquid-cooled power cable assembly **322** includes the liquid cooling assemblies **212**, **214**, a cooler **324**, and power connector pins **326**, **328**. The liquid-cooled power cable assembly **322** is described below in more detail with reference to FIGS. **6**, **7**A, **7**B, and **8**.

The power and liquid transfer assembly **216** enables quick separation of the welding assembly **202** and the liquid-cooled power cable assembly **322** from the mounting assembly **204**. In the example of FIG. **3**, the power and liquid transfer assembly **216** includes a saddle **330**, a saddle cover **332**, a saddle clasp **334**, and saddle clamps **336**. The power and liquid transfer assembly **216** is described below in more detail with reference to FIGS. **4** and **5**.

The example mounting assembly **204** includes a torch body **338**, a neck **340**, and a robot link assembly **342** including, for example, a bracket, a link arm, and a robot mounting disk.

FIG. **4** is a more detailed depiction of an example liquid cooling assembly **400** that may be used to implement the liquid cooling assemblies **208**, **210** of FIG. **2**. FIG. **5** is a cross-section view of the liquid cooling assembly **400** of FIG. **4**.

The liquid cooling assembly **400** includes a power cable socket **402** that holds a power transfer socket **404** and a liquid shutoff valve **406**. The liquid cooling assembly **400** also includes a hose **408** and an internal conductor **410**. The hose **408** is coupled to the power cable socket **402** on a first end and coupled to a power cable fitting **412** on a second end.

The power cable socket **402** receives one of the power connector pins **326**, **328** to transfer cooling liquid and welding current and/or preheating current to a corresponding one of the liquid cooling assemblies **212**, **214**. The power transfer socket **404** enables insertion of the power connector pin **326**, **328**, and transfers current to and/or from an inserted power connector pin **326**, **328**. An example power transfer socket that may be used to implement the power transfer socket **404** is a PowerBud® power contact, sold by Methode Electronics, Inc., which provides multiple contact points between the power transfer socket and an inserted power connector pin **326**, **328**.

The liquid shutoff valve **406** selectively permits flow of liquid from the hose **408** to the power transfer socket **404** and to a connected liquid cooling assembly **212**, **214**. The example liquid shutoff valve **406** is a Schrader valve. However, other types of valves may be used to implement the liquid shutoff valve **406**. When a power connector pin **326**, **328** is inserted (e.g., fully inserted) into the power transfer socket **404**, the power connector pin **326**, **328** displaces (e.g., unseats) a stem **414** from a core **416** of the valve **406**, which permits liquid to flow to and/or from the hose **408**. When the power connector pin **326**, **328** is removed or partially removed, the stem **414** is forced back into the core **416** and stops flow of liquid.

The hose **408** is coupled to the power cable fitting **412** via a ferrule **418** and a fitting nut **420**. The power cable fitting **412** is coupled to a source of weld current and/or preheating current, and is electrically connected to transfer the weld current and/or preheating current to or from the internal conductor **410** of the hose **408**. The hose **408** is also coupled to the power cable socket **402** via a ferrule **418**. The example power cable fitting **412**, the example power cable socket **402**, and/or the hose **408** include hose barbs to secure the hose **408**. However, other methods of securing the hose to the power cable fitting **412** and/or the power cable socket **402** may be used, such as clamps, compression fittings, or any other hose fittings.

During operation, when the power cable fitting **412** is coupled to a power source and a liquid cooling device, and the power cable socket **402** is coupled to a liquid cooling assembly **212**, **214**, the example liquid cooling assembly **400** permits liquid to flow through the power cable fitting **412**, the hose **408**, the valve **406**, the power cable socket **402**, and the power transfer socket **404**, either to or from the liquid cooling device (e.g., based on whether the assembly is configured as the liquid supply or the liquid return). The example liquid cooling assembly **400** also conducts current from and/or to a weld power supply and/or a preheating power supply. For example, the current is conducted through the power cable fitting **412**, the internal conductor **410**, the power cable socket **402**, and the power transfer socket **404**.

FIG. **6** is an exploded view of the example liquid-cooled power cable assembly **322** of FIG. **3**. The liquid-cooled power cable assembly **322** provides cooling liquid supply and return paths from the liquid cooling assemblies **212**, **214** to the welding assembly **202** of FIG. **3**. The liquid-cooled power cable assembly **322** includes the liquid cooling assemblies **212**, **214**, the power connector pins **326**, **328**, a cooling body **602**, and a cooling body cover **604**.

Each of the example liquid cooling assemblies **212**, **214** includes three layers: an inner conductive layer **606***a*, **606***b*; an insulative layer **608***a*, **608***b*; and an outer protective layer **610***a*, **610***b*. The inner conductive layer **606***a*, **606***b* conduct current and liquid, and is constructed of a conductive material such as copper. The insulative layers **608***a*, **608***b* provide electrical insulation between the inner conductive layers **606***a*, **606***b* and the outer protective layers **610***a*, **610***b*. The example insulative layers **608***a*, **608***b* may be silicone, PTFE, PET, and/or any other suitable electrically insulative material or combination of materials. The outer protective layers **610***a*, **610***b* provide rigidity and/or physical protection from damage, such as punctures. The outer protective layers **610***a*, **610***b* may be a rigid material such as aluminum or any other appropriate material or combination of materials.

In some examples, two or more of the layers **606***a*-**610***a*, **606***b*-**610***b* may be combined. For example, the insulative layers **608***a*, **608***b* may also serve as the outer protective layers **610***a*, **610***b*, or vice versa. In other examples, the outer protective layers **610***a*, **610***b* may be omitted.

The inner conductive layers **606***a*, **606***b* are contained within the insulative layers **608***a*, **608***b*. The insulative layers **608***a*, **608***b* are similar contained within the outer protective layers **610***a*, **610***b*.

One of the liquid cooling assemblies **212**, **214** supplies cooling liquid to the cooling body **602**, and the other of the liquid cooling assemblies **212**, **214** receives the liquid from the cooling body **602**. The cooling body **602** circulates the liquid through a tortuous path **612** between a liquid input port and a liquid output port. The cooling body **602** is coupled to the welding assembly **202** to conduct heat from the components in the welding assembly **202** to the liquid, thereby cooling the welding assembly **202**. The cooling body cover **604** is attached to the cooling body **602** to contain the fluid within the tortuous path **606**. In some examples, the cooling body **602** and a cooling body cover **604** may be a single unit (e.g., constructed using additive manufacturing techniques).

FIGS. **7**A, **7**B, and **7**C are views of the example cooler body **602** of FIG. **6**. As illustrated in FIGS. **7**A, **7**B, and **7**C, the tortuous path **612** includes a continuous path around a circumference of the cooler body **602**. In the illustrated example, the liquid cooling assembly **214** supplies cooling liquid to the cooler body **602** and the liquid cooling assembly **212** returns the cooling liquid to a liquid cooler. The cooling liquid follows a flow path **702** (shown using a dotted line) through the tortuous path **612** to increase heat transfer from the welding assembly **202** to the liquid. Continuities A and B from one view to the next are shown in FIGS. **7**A, **7**B, and **7**C.

FIG. **8** is a cross-section view of the liquid cooling assembly **212**, **214** and the power and liquid transfer assembly **216** of FIG. **2** coupled to the liquid cooling assembly **400** of FIG. **4**.

As illustrated in FIG. **8**, the power cable socket **402** is seated in the saddle **330**, which prevents movement of the power cable socket **402**. The example power connector pin **326** is inserted into the power cable socket **402** and the power transfer socket **404**. The power connector pin **326** includes an inner liquid coolant passage **802**, one or more liquid coolant ports **804** to enable liquid to flow into and/or out of the liquid coolant passage **802**, and a seal **806**. When inserted, the power connector pin **326** opens the valve **406** to permit liquid to flow through the valve **406**, the liquid coolant ports **804**, the liquid coolant passage **802**, and the inner conductive layer **606***a*. A retaining ring **808** may be included in the saddle cover **332** to hold the power connector pin **326** in place.

In addition to placing the liquid cooling assembly **212** in fluid communication with the liquid cooling assembly **208**, the example power connector pin **326** also conducts weld current and/or preheating current between the liquid cooling assembly **212** and the liquid cooling assembly **208**. The example inner conductive layer **606***a* is in electrical contact with the power transfer pin **326**, which is a conductive material (e.g., copper) and is in electrical contact with the power transfer socket **404**.

While the examples are described with reference to the liquid cooling assembly **208**, the liquid cooling assembly **212**, and the power connector pin **326**, these examples are similarly applicable to the liquid cooling assembly **210**, the liquid cooling assembly **214**, and the power connector pin **328**.

FIG. **9** illustrates the example welding assembly **202** and the example liquid cooling assemblies **212**, **214** of FIG. **2** disconnected from the remainder of the torch **200** via the power and liquid transfer assembly **216**. For detachment of the example liquid cooling assemblies **212**, **214**, the example saddle clasp **334** is unhooked or otherwise detached from a retention pin **902** on the saddle **330**. When the saddle clasp **334** is unhooked, the power connector pin **328** can be disengaged from the power cable socket **402** and the saddle cover **332** can be simultaneously lifted from the saddle **330**. Conversely, to install the liquid cooling assemblies **212**, **214**, the power connector pins **326**, **328** are inserted into corresponding power cable sockets **402** while the saddle cover **332** is placed onto the saddle **330**. When the power connector pins **326**, **328** and the saddle cover **332** are in place on the saddle **330**, the saddle clasp **334** is hooked into the retention pin **902** to hold the power connector pins **326**, **328** in place.

FIG. **10** is a cross-section view of the example welding assembly **202** of FIG. **2**. The welding assembly **202** is liquid-cooled via the liquid cooling assemblies **212**, **214**. The liquid cooling assemblies **212**, **214** and/or a torch neck **1002** provide weld current and preheating current to the welding assembly **202** for preheating the electrode wire **114** and for generating a welding arc.

The example welding assembly **202** includes the nozzle **302**, the diffuser insulator **304**, the first contact tip **306**, the wire guide **308**, the gas diffuser **310**, the first contact tip insulator **312**, the second contact tip **314**, the second contact tip insulator **316**, the nozzle mount **318**, the nozzle mount clamp **320**, the cooling body **602**, and the cooling body cover **604**. The welding assembly **202** is attached to a torch neck **1002**, through which a wire liner **1004** conveys the electrode wire **114** and/or shielding gas to the welding assembly **202**.

The first contact tip **306** delivers welding current to the electrode wire **114** for arc welding. The first contact tip **306** is threaded into a gas diffuser **310**, which is in turn threaded into the diffuser insulator **304**. The diffuser insulator **304** provides electrical and thermal insulation between the gas diffuser **310** and the nozzle **302**.

The gas diffuser **310** is threaded into the cooling body **602**. The cooling body **602** conducts welding current and/or preheating current from the liquid-cooled power cable assembly **322** (e.g., from the inner conductive layer(s) **606***a*, **606***b*) to the diffuser **310**, which is electrically connected to the first contact tip **306**. The first contact tip insulator **312** and the diffuser insulator **304** provide electrical insulation between the weld current and preheat current path(s) and the nozzle **302**.

The second contact tip **314** is electrically coupled to the torch neck **1002** to conduct preheating current to and/or from the electrode wire **114**. The preheating circuit includes the torch neck **1002**, the second contact tip **314**, the first contact tip **306**, a portion of the electrode wire **1006** between the second contact tip **314** and the first contact tip **306**, the diffuser **310**, the cooling body **602**, and one or both of the inner conductive layers **606***a*, **606***b* in the liquid-cooled power cable assembly **322**.

The second contact tip insulator **316** provides electrical insulation between the second contact tip **314** and the cooling body **602**. The second contact tip insulator **316** includes a seal **1008** (e.g., an o-ring) to reduce or prevent welding gas leakage.

The nozzle mount **318** and the nozzle mount clamp **320** provide an attachment point for threading the welding assembly **202** onto the torch neck **1002**. The nozzle mount **318** physically couples and/or provides support to the liquid-cooled power cable assembly **322** from the torch neck **1002**, which is rigid.

In addition to the welding assembly **202**, the liquid-cooled power cable assembly **322**, and the torch neck **1002** being detachable from the mounting assembly **204** (e.g., via the power and liquid transfer assembly **216** and a conventional disconnection feature between the torch neck **1002** and the mounting assembly **204**), the welding assembly **202** may be completely or partially disassembled to access one or more of the components in the welding assembly **202**.

In the example of FIG. **10**, the first contact tip **306**, the wire guide **308**, and/or the second contact tip **314** are removable via the tip of the nozzle **302**. FIGS. **11**A, **11**B, and **11**C show an example implementation of the first contact tip **306**, FIGS. **12**A and **12**B show an example implementation of the wire guide **308**, and FIGS. **13**A, **13**B, and **13**C show an example implementation of the second contact tip **314**.

As shown in FIGS. **10** and **11**A, a first end **1102** of the first contact tip **306** has a hexagonal cross-section. The hexagonal cross-section enables the first contact tip **306** to be unthreaded from the diffuser **310** via the opening in the nozzle **302**. Other exterior geometries may be used for the cross-section of the first end **1102** of the first contact tip **306**. Additionally or alternatively, an interior geometry may be used (e.g., in combination with a corresponding tool) to unthread the first contact tip **306** from the diffuser **310**.

After removal of the first contact tip **306** from the welding assembly **202** via the nozzle **302**, the wire guide **308** may also be removed via the nozzle **302**. As shown in FIGS. **10**, **12**A, and **12**B, an outer surface **1202** of the wire guide **308** is relatively smooth (e.g., not threaded) and can be inserted into and removed from of an inner diameter **1010** of the cooling body **602** without threading. The wire guide **308** has a wire path **1204** to guide the wire from the second contact tip **314** to the first contact tip **306**. In some examples, the wire guide **308** is a nonconductive material such as ceramic, so that the electrode wire **114** is the only conductive path between the second contact tip **314** and the first contact tip **306**.

As shown in FIGS. **13**A, **13**B, and **13**C, the second contact tip **314** includes a hexagonal cross-section on a first end **1302** of the second contact tip **314**. An interior surface **1304** and/or an exterior surface **1306** (e.g., a head) of the first end **1302** may provide the hexagonal cross-section and/or any other shape that enables the second contact tip to be unthreaded from the torch neck **1002**. The example second contact tip **314** includes threads **1305** to enable the second contact tip **314** to be threaded into the second contact tip insulator **316**. The exterior surface **1306** has a smaller diameter than the major diameter of the threads **1305**, which can improve access to the exterior surface **1306** for removal and/or installation of the second contact tip **314**.

As shown in FIG. **10**, the outer diameter of the second contact tip **314** is equal to or less than the inner diameter **1010** of the cooling body **602** and less than an inner diameter **1012** of the second contact tip insulator **316** to enable the second contact tip **314** to be removed via the tip of the nozzle **302**, the cooling body **602**, and the second contact tip insulator **316**. The first end **1302** may be manipulated (e.g., via a tool inserted through the nozzle **302**) to unthread the second contact tip **314** from the torch neck **1002**, after which the second contact tip **314** can be removed from the welding assembly **202** without disassembly of the welding assembly **202**.

As shown in FIGS. **13**A, **13**B, and **13**C, the second contact tip **314** includes slots **1308** running longitudinally on the exterior of the second contact tip **314** through the threads **1305**. The slots **1308** permit the flow of welding gas from the interior of the torch neck **1002** to the diffuser **310** via the cooling body **602** (e.g., through the interior of the cooling body **602** through and/or around the wire guide **308**.

The second contact tip **314** includes a first bore **1310** having a first diameter. The electrode wire **114** makes electrical contact with the first bore **1310**. The example second contact tip **314** may also have a second, larger bore **1312** on a rear side of the contact tip **314** from the first bore **1310**. The length of the second bore **1312** may be selected to control a contact length of the first bore **1310**.

As illustrated in FIG. **10**, the example contact tip **314** may have an insert **1012** inserted within the first bore **1310** to improve contact with the electrode wire **114**, improve current transfer with the electrode wire **114**, and/or improve mechanical strength at operating temperatures.

FIGS. **14**A and **14**B illustrate views of the example diffuser **310** of FIGS. **3** and **10**. As discussed above with reference to FIG. **10**, the diffuser **310** includes two sets of exterior threads for installation into the diffuser insulator **304** and the cooling body **602**, and a set of interior threads for installation of the first contact tip **306** into the diffuser **310**. The diffuser **310** includes gas outlets **1402** to enable the flow of gas from the inner diameter **1010** of the cooling body **602** to the nozzle **302** for output to the weld.

FIG. **15**A illustrates a conventional robotic welding torch **1500** having a first tool center point distance and torch neck angle. FIG. **15**B illustrates an example implementation of the liquid-cooled welding torch **200** of FIG. **2** configured to replace the conventional torch **1500** of FIG. **15**A while maintaining a same tool center point distance and torch neck angle.

The tool center point distance **1502** of the conventional torch **1500** is a function of a stickout distance **1504**, a nozzle length **1506**, a nozzle angle **1508**, a neck bend angle **1510**, a tool center point area **1512**, and a spacer width **1514**. The tool center point area **1512** (e.g., Area_{TCP}) is defined using Equation 1 below:

$$\text{Area}_{TCP}=0.5*((\text{TCP}-\text{spacer width }1514)^2*\text{TAN}(\text{nozzle angle }1508)+((\text{TCP}-\text{spacer width }1514)-(\text{nozzle length }1506+\text{stickout }1504)*\text{COS}(\text{nozzle angle }1508))^2*(\text{TAN}(\text{nozzle angle }1508-\text{neck bend angle }1510)-1)) \quad \text{(Equation 1)}$$

The example welding assembly **202** described above with reference to FIGS. **10**, **11A-11C**, **12**A, **12**B, **13A-13C**, **14**A, and/or **14**B may have a same nozzle length **1506** as conventional nozzles. In other examples, the welding assembly **202** may require a longer nozzle **302** than a nozzle of the conventional torch. In some examples, such as the welding torch described below with reference to FIGS. **19-23**, the welding assembly may have a nozzle that is shorter than conventional nozzles. However, the length of the example torch neck **1002** and/or the length and/or one or more dimensions of the example mounting assembly **204** may be adjusted to compensate for differences in the nozzle length.

Using the example welding assembly **202** disclosed herein, the example liquid-cooled welding torch **200** may be dimensioned to be a replacement for any standard tool center point distance (e.g., 350 mm, 400 mm, 450 mm, 500 mm, etc.) and/or torch neck angle (e.g., 0 degree, 22 degree, 35 degree, 45 degree, etc.) to maintain the same TCP, torch neck angle, and tool center point area after replacement. In other words, disclosed example welding assemblies **202** and/or liquid-cooled welding torches **200** may be used as replacements for conventional robotic weld torches such that a robot on which the replacement occurs does not require reprogramming or recalibration of new tool center point(s) or torch neck angle(s). After replacement of the conventional welding torch with disclosed example liquid-cooled welding torches, the robot subject to replacement is capable of higher deposition rates, improved welding starts, and/or other advantages over conventional welding torches. As a result, reprogramming of welding voltages, currents, and/or torch travel speeds may be performed to realize the advantages of the liquid-cooled welding torch **200** for previously programmed welding tasks.

In addition to the tool center point distance **1502**, the stickout distance **1504**, the nozzle length **1506**, the nozzle angle **1508**, the neck bend angle **1510**, the tool center point area **1512**, and the spacer width **1514** dimensions of the conventional welding torch **1500**, the example welding torch **200** includes a preheat distance **1516** within the nozzle. The nozzle length **1506** is subdivided into the stickout distance **1504**, the preheat distance **1516**, and a neck-to-contact tip length **1518**. The conventional torch **1500** may be considered to have a preheat distance **1516** of **0**. By replacing a conventional weld torch **1500** with a weld torch **200** having substantially the same tool center point distance **1502**, the stickout distance **1504**, the nozzle length **1506**, the nozzle angle **1508**, the neck bend angle **1510**, and the tool center point area **1512**, the replacement reduces the programming needed to avoid an increased risk of collisions.

Tables 1 and 2 below illustrates example comparisons of the dimensions **1502-1516** for two example tool center point distances **1502**, 350 mm and 400 mm.

TABLE 1

350 mm TCP Dimensions for Conventional and Disclosed example welding torches

#	TCP (mm)	TCP (in)	Stickout (in)	Preheat (in)	Neck-to-contact tip length (in)	Nozzle length (in)	Nozzle angle (deg.)	Neck angle (deg.)	TCP area (sq. in.)
1	350	13.78	0.59	0.00	4.33	4.92	45	22	51.59
2	350	13.78	0.75	3.29	1.78	5.82	45	22	54.61
3	350	13.78	0.75	2.40	1.78	4.93	45	22	51.61

TABLE 2

400 mm TCP Dimensions for Conventional and Disclosed example welding torches

#	TCP (mm)	TCP (in)	Stickout (in)	Preheat (in)	Neck-to-contact tip length (in)	Nozzle length (in)	Nozzle angle (deg.)	Neck angle (deg.)	TCP area (sq. in.)
4	400	15.75	0.59	0.00	4.33	4.92	45	22	66.44
5	400	15.75	0.75	3.29	1.78	5.82	45	22	70.17
6	400	15.75	0.75	2.40	1.78	4.93	45	22	66.46

A welding torch having a preheat length of 3.29 inches (e.g., torches 2 and 5 of Tables 1 and 2 above) may be used with an air-cooled torch. A welding torch having a preheat length of 2.40 inches results in a nozzle length **1506** and TCP area **1512** of a welding torch **200** that substantially match the nozzle length and TCP area **1512** of the conventional torch **1500**. However, the current density may increase enough to require an increase in the radius of the welding assembly **202** (e.g., increased components in the welding assembly **202**) to continue to use air cooling (as in torches 2 and 5 of Tables 1 and 2). Additionally or alternatively, the preheat distance of 2.40 inches may be used with the example liquid cooled welding torch **200** disclosed herein.

Any of the dimensions of Tables 1 and 2 (or similar dimensions) may be selected based on a specification of another of the dimensions. For example, the preheating length (and, thus, the dimensions of the welding assembly) may be selected based on any of the TCP, the stickout, the neck-to-contact tip length, the nozzle length, the nozzle angle, the neck angle, and/or the TCP area. Additionally or alternatively, the neck-to-contact tip length is based on at least one of a nozzle length, a preheat distance, a nozzle angle, or a neck angle.

Preheat lengths **1516** that are longer than the 3.29 inches of the examples of Tables 1 and 2 may result in a torch envelope that is larger than the envelope of the conventional torches **1500** by more than an acceptable amount. Torches having an envelope that is excessively large may require more robot programming to serve as a replacement for a conventional torch and/or has a higher chance of collision during operation. Additional programming and collisions are undesirable effects of replacement, and disclosed examples reduce or prevent such effects while providing the benefits of electrode preheating at the welding assembly **202**.

While the example welding assembly **202** includes the first contact tip **306** and the second contact tip **314** such that both of the contact tips **306**, **314** are on a distal end of the bend in the torch neck **1002**, in some other examples the second contact tip **314** is on a proximal side of the bend in the torch neck **1002**. Additionally or alternatively, a third contact tip is further located on the proximal side of the bend in the torch neck **1002** so that preheating occurs between the second contact tip **314** (on either side of the bend) and the third contact tip (on the proximal side of the bend).

When the electrode wire **114** is heated beyond a particular temperature, the column strength of the electrode wire **114** may be reduced to a point that the heated electrode wire **114** can no longer be pushed around the bend in the torch neck **1002** without buckling. In some such examples, the liquid-cooled welding torch **200** is provided with a pull motor to assist the push motor located in the wire feeder.

The bend in the torch neck **1002** may be provided with ceramic bearings to reduce the friction force between the wire liner **1004** and the electrode wire **114**, which increases the temperature to which the electrode wire **114** may be preheated before buckling becomes likely.

In some examples, the length between the first and second contact tips **306**, **314** (e.g., the preheat length) is adjustable to change the length of the electrode wire **114** that is being preheated. As the preheat length increases, the energy added to the electrode wire **114** is increased per unit of current. To change the preheat length, one or both of the contact tips **306**, **314** may be configured to be translated in the axial direction via manual and/or automatic methods.

Using the second contact tip **314** as an example, the second contact tip **314** may be threaded into an intermediate device between the second contact tip **314** and the torch neck **1002**. The intermediate device may be automatically rotated (e.g., with a motor coupled to the contact tip) and/or manually rotated (e.g., with a thumb wheel or other device configured to cause rotation in the contact tip) while limiting rotation of the second contact tip **314**, which causes the threads of the second contact tip **314** to carry the second contact tip **314** toward or away from the first contact tip **306**.

Additionally or alternatively, the first and/or second contact tips **306**, **314** may be configured to be reversible to change the preheat length. For example, if the first contact tip **306** has a contact location with the electrode wire **114** that is closer than a midpoint of the first contact tip **306** to the second contact tip **314**, reversing the first contact tip **306** changes the contact location with the electrode wire **114** and extends the preheat length. In some examples, different contact tips have different contact points, so that changing contact tips changes the preheat length. In some other examples, the welding assembly **202** may be replaced with a different welding assembly that has a different preheat length such as different spacing between the contact tips **306**, **314** (which may require a different robotic program to be run that accounts for a different nozzle length).

The change in preheat length may be automatically controlled based on, for example, a temperature of the electrode wire **114** and/or based on a desired preheat level or heat input to the weld specified by a user. In some examples, a current controlled control loop is used to control preheat current when the preheat length is automatically adjustable.

The power and liquid transfer assembly **216** is attached to the torch body **338** on a side of the torch body **338** opposite the mounting assembly **204**, or opposite a direction of the bend in the torch neck **1002**. Because the power and liquid transfer assembly **216** increasing a volume of the torch **200**, locating the power and liquid transfer assembly **216** opposite the mounting assembly **204** and/or opposite a direction of the bend in the torch neck **1002** may reduce the chances of collision with a workpiece when using the same program with the replacement preheating weld torch **200** as used with a conventional weld torch.

In still other examples, the welding assembly **202** may be provided with a wire oscillator to cause physical oscillation or weave at a tip of the electrode wire **114**. An example implementation of the wire oscillator that may be used to provide wire oscillation is described in U.S. Pat. No. 4,295,031. Using both the wire oscillator and the contact tips **306**, **314**, disclosed example welding torches may provide both wire oscillation and resistive preheating to a weld to further improve deposition rates and weld quality.

FIG. **16** is a cross section of an example welding cable **1600** that may be used to provide cooling liquid, welding current, and preheating current to a welding torch, and to carry cooling liquid away from the welding torch. The example welding cable **1600** may be used instead of the liquid cooling assemblies **208**, **210**, in cases in which the first contact tip **306** is part of the preheating circuit and the welding circuit.

The welding cable **1600** is a coaxial-type welding cable, in which the electrode wire **114** is fed through a wire guide **1602**. The wire guide **1602** is surrounded by a jacket **1604**. A first conductor **1606** provides a first electrical path for preheating current, or welding current and preheating current. The first conductor **1606** may be, for example, a copper sheath or webbing rated to conduct welding current. The first conductor **1606** is surrounded by a jacket **1608**.

A second conductor **1610** provides a second electrical path for preheat current, or welding current and preheating current. In the example of FIG. **16**, a first one of the first conductor **1606** or the second conductor **1610** provides a path for the preheating current and is coupled to a preheating power supply. The second conductor **1610** is surrounded by a jacket **1612**. In some examples, another protective layer may be present outside of the jacket **1612** to protect the welding cable **1600** from damage. In some examples, the jacket **1612** provides both physical and electrical protection to the cable **1600**.

An annulus **1614** between the jacket **1604** and the first conductor **1606** and/or the jacket **1608** conducts cooling liquid in a first direction (e.g., from a liquid cooler to the welding torch, from the welding torch to the liquid cooler). An annulus **1616** between the jacket **1608** and the second conductor **1610** and/or the jacket **1612** conducts the cooling liquid in a second direction opposite the liquid flow direction in the annulus **1614**.

FIG. **17** illustrates a functional diagram of an example welding system **1700** including the example welding torch **200** of FIG. **2**, and which may be used with the welding system **100** of FIG. **1**. The welding system **1700** includes the weld torch **200** having the first contact tip **306** and a second contact tip **314**. The system **1700** further includes the electrode wire **114** fed from a wire feeder **1702** having a wire drive **1704** and a wire spool **1706**, a preheating power supply **1708**, and a welding power supply **1710**. The system **1700** is illustrated in operation as producing a welding arc **1712** between the electrode wire **114** and a workpiece **106**.

In operation, the electrode wire **114** passes from the wire spool **1706** through the second contact tip **314** and the first contact tip **306**, between which the preheating power supply **1708** generates a preheating current to heat the electrode wire **114**. Specifically, in the configuration shown in FIG. **17**, the preheating current enters the electrode wire **114** via the second contact tip **314** (e.g., via the wire drive **1704** and/or the torch neck **1002** of FIG. **10**) and exits via the first contact tip **306**. At the first contact tip **306**, a welding current may also enter the electrode wire **114** (e.g., via the liquid cooling assemblies **208** and **212**, and/or **210** and **214**. The welding current is generated, or otherwise provided by, the welding power supply **1710**. The welding current exits the electrode wire **114** via the workpiece **106**, which in turn generates the welding arc **1712**. When the electrode wire **114** makes contact with a target metal workpiece **106**, an electrical circuit is completed and the welding current flows through the electrode wire **114**, across the metal work piece(s) **106**, and returns to the welding power supply **1710**. The welding current causes the electrode wire **114** and the parent metal of the work piece(s) **106** in contact with the electrode wire **114** to melt, thereby joining the work pieces as the melt solidifies. By preheating the electrode wire **114**, a welding arc **1712** may be generated with drastically reduced arc energy. Generally speaking, the preheating current is proportional to the distance between the contact tips **306**, **314** and the electrode wire **114** size.

The welding current is generated, or otherwise provided by, a welding power supply **1710**, while the preheating current is generated, or otherwise provided by, the preheating power supply **1708**. The preheating power supply **1708** and the welding power supply **1710** may ultimately share a common power source (e.g., a common generator or line current connection), but the current from the common power source is converted, inverted, and/or regulated to yield the two separate currents—the preheating current and the welding current. For instance, the preheat operation may be facilitated with a single power source and associated converter circuitry, in which case three leads may extend from a single power source.

During operation, the system **1700** establishes a welding circuit to conduct welding current from the welding power supply **1710** to the first contact tip **306** via the liquid cooling assemblies **208** and **212** and/or **210** and **214**, and returns to the power supply **1710** via the welding arc **1712**, the workpiece **106**, and a work lead **1718**. To enable connection between the welding power supply **1710** and the first contact tip **306** and the workpiece **106**, the welding power supply **1710** includes terminals **1720**, **1722** (e.g., a positive terminal and a negative terminal).

During operation, the preheating power supply establishes a preheating circuit to conduct preheating current through a section **1726** of the electrode wire **114**. To enable connection between the preheating power supply **1708** and the contact tips **306**, **314**, the preheating power supply **1708** includes terminals **1728**, **1730**. The preheating current flows from the welding power supply **1710** to the second contact tip **314** (e.g., via the torch neck **1002**), the section **1726** of the electrode wire **114**, the first contact tip **306**, and returns to the preheating power supply **1708** via a cable **1732** connecting the terminal **1720** of the welding power supply **1710** to the terminal **1730** of the preheating power supply **1708**.

Because the preheating current path is superimposed with the welding current path over the connection between the first contact tip **306** and the power supplies **1708**, **1710**, the cable **1732** may enable a more cost-effective single connection between the first contact tip **306** and the power supplies **1708**, **1710** (e.g., a single cable) than providing separate connections for the welding current to the first contact tip **306** and for the preheating current to the first contact tip **306**. In other examples, the terminal **1730** of the preheating power supply **1708** is connected to the first contact tip **306** via a separate path than the path between the first contact tip **306** and the welding power supply **1710**. For example, the welding current may be conducted via the liquid cooling assemblies **208** and **212** while the preheating current is conducted via the liquid cooling assemblies **210** and **214** (or vice versa).

In some examples, the welding torch may include a push-pull wire feed system by including a feed motor located at or near the weld torch to pull the electrode wire **114**. In some examples, the inclusion of the pulling feed motor enables the portion of the electrode wire **114** that is preheated to a different location along the wire feed path than in the examples of FIGS. **2**, **3**, and **10**. For example, the second contact tip **314** may be moved into the neck **1002** (e.g., prior to the bend in the torch neck **1002** in the feed direction of the electrode wire **114**) and/or in the torch body (e.g., the mounting assembly **204** of FIG. **2**) and/or multiple contact tips may be positioned at locations along the length of the electrode wire **114** to provide a preheating circuit that is separate from the welding circuit (e.g., does not share a same contact tip with the welding circuit) and/or provides an additional preheating circuit (e.g., a first preheating current applied to a first portion of the electrode wire **114** and a second preheat current applied to a second portion of the preheating wire). In some examples, the idler roller of a push-pull wire feed system may function as a contact tip to conduct preheating current. By moving all or a portion of the preheating circuit to the wire source side of the bend in the torch neck **1002** (e.g., the side of the bend closer to the wire spool in the electrode feed path), the size of the welding assembly may be reduced, the preheat length may be increased, and/or the preheating current may be reduced. Reduction in the size of the welding assembly and reduction in the preheating current enables torch dimensions that are closer to those of conventional, non-resistive preheating torches, further improving the ease of replacement of conventional torches with torches providing resistive preheating.

FIG. **18** is a block diagram of an example implementation of the power supplies **1708**, **1710** of FIG. **17**. The example power supply **1708**, **1710** powers, controls, and supplies consumables to a welding application. In some examples, the power supply **1708**, **1710** directly supplies input power to the welding tool **108**. In the illustrated example, the power supply **1708**, **1710** is configured to supply power to welding operations and/or preheating operations. The example power supply **1708**, **1710** also provides power to a wire feeder to supply the electrode wire **114** to the welding tool **108** for various welding applications (e.g., GMAW welding, flux core arc welding (FCAW)).

The power supply **1708**, **1710** receives primary power **1808** (e.g., from the AC power grid, an engine/generator set, a battery, or other energy generating or storage devices, or a combination thereof), conditions the primary power, and provides an output power to one or more welding devices and/or preheating devices in accordance with demands of the system. The primary power **1808** may be supplied from an offsite location (e.g., the primary power may originate from the power grid). The power supply **1708**, **1710** includes a power converter **1810**, which may include transformers, rectifiers, switches, and so forth, capable of converting the AC input power to AC and/or DC output power as dictated by the demands of the system (e.g., particular welding processes and regimes). The power converter **1810** converts input power (e.g., the primary power **1808**) to welding-type power based on a weld voltage setpoint and outputs the welding-type power via a weld circuit.

In some examples, the power converter **1810** is configured to convert the primary power **1808** to both welding-type power and auxiliary power outputs. However, in other examples, the power converter **1810** is adapted to convert primary power only to a weld power output, and a separate auxiliary converter is provided to convert primary power to auxiliary power. In some other examples, the power supply **1708**, **1710** receives a converted auxiliary power output directly from a wall outlet. Any suitable power conversion system or mechanism may be employed by the power supply **1708**, **1710** to generate and supply both weld and auxiliary power.

The power supply **1708**, **1710** includes a controller **1812** to control the operation of the power supply **1708**, **1710**. The power supply **1708**, **1710** also includes a user interface **1814**. The controller **1812** receives input from the user interface **1814**, through which a user may choose a process and/or input desired parameters (e.g., voltages, currents, particular pulsed or non-pulsed welding regimes, and so forth). The user interface **1814** may receive inputs using any input device, such as via a keypad, keyboard, buttons, touch screen, voice activation system, wireless device, etc. Furthermore, the controller **1812** controls operating parameters based on input by the user as well as based on other current operating parameters. Specifically, the user interface **1814** may include a display **1816** for presenting, showing, or indicating, information to an operator. The controller **1812** may also include interface circuitry for communicating data to other devices in the system, such as the wire feeder. For example, in some situations, the power supply **1708**, **1710** wirelessly communicates with other welding devices within the welding system. Further, in some situations, the power supply **1708**, **1710** communicates with other welding devices using a wired connection, such as by using a network interface controller (NIC) to communicate data via a network (e.g., ETHERNET, 10baseT, 10base100, etc.). In the example of FIG. **18**, the controller **1812** communicates with the wire feeder via the weld circuit via a communications transceiver **1818**.

The controller **1812** includes at least one controller or processor **1820** that controls the operations of the welding power supply **1802**. The controller **1812** receives and processes multiple inputs associated with the performance and demands of the system. The processor **1820** may include one or more microprocessors, such as one or more "general-purpose" microprocessors, one or more special-purpose microprocessors and/or ASICS, and/or any other type of processing device. For example, the processor **1820** may include one or more digital signal processors (DSPs).

The example controller **1812** includes one or more storage device(s) **1823** and one or more memory device(s) **1824**. The storage device(s) **1823** (e.g., nonvolatile storage) may include ROM, flash memory, a hard drive, and/or any other suitable optical, magnetic, and/or solid-state storage medium, and/or a combination thereof. The storage device **1823** stores data (e.g., data corresponding to a welding application), instructions (e.g., software or firmware to perform welding processes), and/or any other appropriate data. Examples of stored data for a welding application include an attitude (e.g., orientation) of a welding torch, a distance between the contact tip and a workpiece, a voltage, a current, welding device settings, and so forth.

The memory device **1824** may include a volatile memory, such as random access memory (RAM), and/or a nonvolatile memory, such as read-only memory (ROM). The memory device **1824** and/or the storage device(s) **1823** may store a variety of information and may be used for various purposes. For example, the memory device **1824** and/or the storage device(s) **1823** may store processor executable instructions **1825** (e.g., firmware or software) for the processor **1820** to execute. In addition, one or more control regimes for various welding processes, along with associated settings and parameters, may be stored in the storage device **1823** and/or memory device **1824**, along with code configured to provide a specific output (e.g., initiate wire feed, enable gas flow, capture welding current data, detect short circuit parameters, determine amount of spatter) during operation.

In some examples, the welding power flows from the power converter **1810** through a weld cable **1826**. The example weld cable **1826** is attachable and detachable from weld studs at each of the power supply **1708**, **1710** (e.g., to enable ease of replacement of the weld cable **1826** in case of wear or damage). Furthermore, in some examples, welding data is provided with the weld cable **1826** such that welding power and weld data are provided and transmitted together over the weld cable **1826**. The communications transceiver **1818** is communicatively coupled to the weld cable **1826** to communicate (e.g., send/receive) data over the weld cable **1826**. The communications transceiver **1818** may be implemented based on various types of power line communications methods and techniques. For example, the communications transceiver **1818** may utilize IEEE standard P1901.2 to provide data communications over the weld cable **1826**. In this manner, the weld cable **1826** may be utilized to provide welding power from the power supply **1708**, **1710** to the wire feeder and the welding tool **108**. Additionally or alternatively, the weld cable **1826** may be used to transmit and/or receive data communications to/from the wire feeder and the welding tool **108**. The communications transceiver **1818** is communicatively coupled to the weld cable **1826**, for example, via cable data couplers **1827**, to characterize the weld cable **1826**, as described in more detail below. The cable data coupler **1827** may be, for example, a voltage or current sensor.

In some examples, the power supply **1708**, **1710** includes or is implemented in a wire feeder.

The example communications transceiver **1818** includes a receiver circuit **1821** and a transmitter circuit **1822**. Generally, the receiver circuit **1821** receives data transmitted by the wire feeder via the weld cable **1826** and the transmitter circuit **1822** transmits data to the wire feeder via the weld cable **1826**. As described in more detail below, the communications transceiver **1818** enables remote configuration of the power supply **1708**, **1710** from the location of the wire feeder and/or compensation of weld voltages by the power supply **1708**, **1710** using weld voltage feedback information transmitted by the wire feeder **104**. In some examples, the receiver circuit **1821** receives communication(s) via the weld circuit while weld current is flowing through the weld circuit (e.g., during a welding-type operation) and/or after the weld current has stopped flowing through the weld circuit (e.g., after a welding-type operation). Examples of such communications include weld voltage feedback information measured at a device that is remote from the power supply **1708**, **1710** (e.g., the wire feeder) while the weld current is flowing through the weld circuit

Example implementations of the communications transceiver **1818** are described in U.S. Pat. No. 9,012,807. The entirety of U.S. Pat. No. 9,012,807 is incorporated herein by reference. However, other implementations of the communications transceiver **1818** may be used.

The example wire feeder **104** also includes a communications transceiver **1819**, which may be similar or identical in construction and/or function as the communications transceiver **1818**.

In some examples, a gas supply **1828** provides shielding gases, such as argon, helium, carbon dioxide, and so forth, depending upon the welding application. The shielding gas flows to a valve **1830**, which controls the flow of gas, and if desired, may be selected to allow for modulating or regulating the amount of gas supplied to a welding application. The valve **1830** may be opened, closed, or otherwise operated by the controller **1812** to enable, inhibit, or control gas flow (e.g., shielding gas) through the valve **1830**. Shielding gas exits the valve **1830** and flows through a cable **1832** (which in some implementations may be packaged with the welding power output) to the wire feeder which provides the shielding gas to the welding application. In some examples, the power supply **1708**, **1710** does not include the gas supply **1828**, the valve **1830**, and/or the cable **1832**.

FIG. **19** illustrates another example liquid-cooled welding torch **1900**. Like the torch **200** of FIGS. **2-14**B, the example liquid-cooled welding torch **1900** resistively preheats an electrode wire **114** via multiple contact points (e.g., contact tips) in the torch **1900**.

The torch **1900** of FIG. **19** includes a welding assembly **1902**, a mounting assembly **1904**, a weld cable **1906**, liquid cooling assemblies **1908**, **1910**, **1912**, **1914**, and a power and liquid transfer assembly **1916**. The example liquid-cooled welding torch **1900** may be used to replace conventional robotic welding torches with resistive preheating-enabled welding torches having a same tool center point (TCP).

The welding assembly **1902** receives weld current and preheating current, conducts the weld current to the electrode wire **114**, and conducts the preheating current through a portion of the electrode wire **114**. The example welding assembly **1902** is liquid-cooled by liquid provided via the liquid cooling assemblies **1908-214**. The example welding assembly **1902** of FIG. **19** receives the weld current via one or more of the weld cable **1906**, the liquid cooling assemblies **1908** and **1912**, and/or the liquid cooling assemblies **1910** and **1914**. Because the workpiece provides the return path for the weld current to the power supply, no return path is provided via the weld cable **1906** or the liquid cooling assemblies **1908**. The weld cable **1906** is a air-cooled (or gas-cooled) cable. However, the weld cable **1906** may also be liquid-cooled.

The example welding assembly **1902** receives the preheating current via the weld cable **1906**, the liquid cooling assemblies **1908** and **1912**, and/or the liquid cooling assemblies **1910** and **1914**. In the example of FIG. **19**, the weld current is conducted via a different one of the weld cable **1906**, the liquid cooling assemblies **1908** and **1912**, or the liquid cooling assemblies **1910** and **1914** than the preheating current that has the same polarity (i.e., current flow direction). The welding assembly **1902** conducts the preheating current through a section of the electrode wire **114** to heat the electrode wire via resistive heating (e.g., I^2R heating). The preheat current then returns to a preheating power supply via a different one of weld cable **1906**, the liquid cooling assemblies **1908** and **1912**, or the liquid cooling assemblies **1910** and **1914** to complete a preheating circuit.

In the example of FIG. **19**, the weld current path, the preheating current supply path, and the preheating current return path may all be different ones of the weld cable **1906**, the liquid cooling assemblies **1908** and **1912**, and the liquid cooling assemblies **1910** and **1914**. In some examples, the weld current path may be superimposed with the preheating current supply path or the preheating current return path to reduce the net current in the conductor. For example, if the weld current is 300 A and the preheating current is 100 A, the weld current and the preheating current may be superimposed to result in a net current of 1900 A.

As described in more detail below, the welding assembly **1902** and the liquid cooling assemblies **1912**, **1914** may be separated from the remainder of the liquid-cooled welding torch **1900** via the power and liquid transfer assembly **1916**, and may be simultaneously separated from the mounting assembly **1904**.

FIG. **20** is an exploded view of the example welding assembly **1902** of the welding torch **1900** of FIG. **19**. The welding assembly **1902** includes a front portion **2002** and a rear portion **2004**. FIG. **21** is a cross-sectional plan view of the example welding assembly **1902** of FIG. **19** in which the front portion **2002** is coupled to the rear portion **2004**. As described in more detail below, the front portion **2002** is detachable from the rear portion to enable access to a rear contact tip **2006** (e.g., a preheating contact tip).

The front portion **2002** includes a nozzle **2008**, a nozzle insulator **2010**, a front contact tip **2012**, a diffuser **2014**, a wire guide **2016**, a cooling body **2018**, a hand nut **2020**, and a hand nut insulator **2022**. The rear portion **2004** includes a valve assembly **2024**, a valve assembly insulator **2026**, and a valve assembly housing **2028**.

The example hand nut **2020** secures the cooling body **2018**, and the components **2008-2016** connected to the cooling body **2018**, to the rear portion **2004**. In the example of FIG. **20**, the hand nut **2020** has internal screw threads to be threaded onto external screw threads **2030** of the valve assembly **2024**. A tapered edge **2032** of the hand nut **2020** mates with a shoulder of the cooling body **2018** to force the cooling body **2018** toward the valve assembly **2024**. The hand nut insulator **2022** electrically insulates the hand nut to reduce or prevent an operator contacting weld voltage and/or preheating voltage via the hand nut **2020**.

The example valve assembly **2024** includes fluid valves **2034***a*, **2034***b* positioned within fluid channels **2036***a*, **2036***b*, respectively. The fluid channels **2036***a*, **2036***b* are in fluid communication with the liquid cooling assemblies **1912**, **1914** to circulate fluid through the welding assembly **1902**. The example valves **2034***a*, **2034***b* are Shrader valves that cut off fluid flow when the valves are not actuated. To actuate the valves, the example cooling body **2018** includes valve actuators **2038***a*, **2038***b*, which are located within channels **2040***a*, **2040***b* of the cooling body **2018**. The valve actuators **2038***a*, **2038***b* actuate the valves **2034***a*, **2034***b* when the front portion **2002** (including the cooling body **2018**) is secured to the rear portion **2004**.

When the valves are actuated, the cooling body **2018** is in fluid communication with the liquid cooling assemblies **1912**, **1914**. The example cooling body **2018** includes one or more internal channels to direct fluid from one of the valve actuators **2038***a*, **2038***b* to a second one of the valve actuators **2038***a*, **2038***b*. In other words, one of the valve actuators **2038***a*, **2038***b* is an inlet to the channel(s) **2102** in the cooling body **2018** from one of the liquid cooling assemblies **1912**, **1914** and the other of the valve actuators **2038***a*, **2038***b* is an outlet from the channel(s) **2102** to the other of the liquid cooling assemblies **1912**, **1914**. The example channels **2102** run circumferentially within the cooling body **2018** between the valve actuators **2038***a*, **2038***b* to transfer heat from the nozzle **2008** to the fluid within the channels **2102**.

The example nozzle **2008** includes internal threads **2104** that couple the nozzle **2008** to a threaded ring **2042** coupled to an exterior of the cooling body **2018**. When coupled, heat from the nozzle **2008** is transferred to the cooling body **2018** for further dissipation to the cooling liquid.

When secured (e.g., threaded together), the cooling body **2018** and the valve assembly **2024** are in electrical contact to transfer welding current and/or preheating current with the front contact tip **2012** via the diffuser **2014**. The welding current and/or preheating current are conducted via one or more of the liquid cooling assemblies **1912**, **1914**. For example, one or both of the liquid cooling assemblies **1912**, **1914** include a conductor layer electrically coupled to the front contact tip **2012** via the diffuser **2014**, the cooling body **2018**, and the valve assembly **2024**. Preheating current is conducted to the rear contact tip **2006** from the weld cable **1906** via a torch neck **2044**, which includes one or more layers of conductors, a wire liner to transfer the electrode wire **114**, and an annulus to provide gas flow to the weld assembly **1902** for output to the weld via the diffuser **2014**.

As illustrated in FIG. **20**, the liquid cooling assemblies **1912**, **1914** may be secured to the torch neck **2044** via bracket **2046** or other attachment technique.

The example wire guide **2016** may be similar or identical to the wire guide **308** of FIG. **3**. The wire guide **2016** is held within a bore in the diffuser **2014**. The nozzle insulator **2010** electrically and thermally insulates the nozzle **2008** from the front contact tip **2012** and the diffuser **2014**. The nozzle **2008** is electrically insulated from the cooling body **2018** by one or more additional electrical insulator(s) **2110** located on the cooling body **2018**. The example electrical insulator(s) **2110** may be thermally conductive to conduct heat from the nozzle **2008** to the cooling body **2018**. Polyether ether ketone (PEEK) and/or other thermoplastics may be used to implement the example electrical insulator(s) **2110**.

The example cooling body **2018** may include any number of electrical insulators and/or fluid seals to enable conduction of current to the diffuser **2014**, reduce or prevent conduction of current to unneeded or undesired components (e.g., exterior components), and/or to reduce or prevent fluid leaks from the cooling body **2018**. In the example of FIG. **21**, the cooling body **2018** includes an inner body **2106** defining the channel(s) **2102** and a cover **2108** configured to enclose the channels **2102**.

The example rear contact tip **2006** may be similar or identical to the second contact tip **314** of FIGS. **3** and **13**A-**13**C.

FIG. **22** is a cross-sectional plan view of the example power and liquid transfer assembly **1916** of FIG. **19**. FIG. **23** is a partially exploded elevation view of the example power and liquid transfer assembly **1916** of FIG. **19**.

The example power and liquid transfer assembly **1916** is similar to the power and liquid transfer assembly **216** of FIGS. **2**, **3**, and **8**, in that the power and liquid transfer assembly **1916** includes multiple liquid transfer valves, corresponding valve actuators, and one or more electrical power transfer sockets, and in that the power and liquid transfer assembly **1916** enables disconnection of the liquid cooling assemblies **1912**, **1914** from the power and liquid transfer assembly **1916** and cuts off fluid transfer in response to disconnection.

The example power and liquid transfer assembly **1916** is coupled to the liquid cooling assemblies **1908**, **1910**, which provide supply and return lines for the cooling liquid to a liquid cooler. The example liquid cooling assembly **1908** includes an internal conductor **2202** to conduct welding current (e.g., to the welding power supply **1710** of FIG. **17**) and/or preheating current (e.g., to the preheating power supply **1708**). The conductor **2202** is in electrical contact with a socket **2204**, which permits fluid to flow from an exterior of the socket **2204** to an interior of the socket **2204**, into which a fluid fitting **2206** of the power and liquid transfer assembly **1916** is fitted to make a fluid connection with the liquid cooling assembly **1908** and electrical contact with the socket **2204**. In the example of FIG. **22**, the liquid cooling assembly **1910** only includes tubing to transfer liquid, and does not include an internal conductor or a socket. In other examples, the liquid cooling assembly **1910** also includes a conductor and has a construction similar or identical to the liquid cooling assembly **1908**.

Each of the example liquid cooling channels of the power and liquid transfer assembly **1916** includes a liquid shutoff valve **2208***a*, **2208***b* within a fluid socket **2209***a*, **2209***b*. The channel coupled to the liquid cooling assembly **1908** (e.g., carrying current and liquid) includes a power transfer socket **2210**. The channel coupled to the liquid cooling assembly **1910** (e.g., carrying only liquid) may include a non-conductive socket **2212** having similar, the same, or different dimensions as the power transfer socket **2210**.

The power cable socket **2210** receives a power connector pin **2214** of the liquid cooling assembly **1912** to transfer cooling liquid and welding current and/or preheating current to the liquid cooling assembly **1912**. The nonconductive socket **2212** likewise receives a power connector pin or other pin corresponding to the dimensions of the socket **2212**. The power transfer socket **2210** enables insertion of the power connector pin **2214**, and transfers current to and/or from an inserted power connector pin **2214**. An example power transfer socket that may be used to implement the power transfer socket **2210** is a PowerBud® power contact, sold by Methode Electronics, Inc., which provides multiple contact points between the power transfer socket and an inserted power connector pin **2214**.

The liquid shutoff valves **2208***a*, **2208***b* selectively permit flow of liquid from liquid cooling assemblies **1908**, **1910** to the sockets **2210**, **2212** and to a connected liquid cooling assembly **1912**, **1914**. The example liquid shutoff valves **2208***a*, **2208***b* are Schrader valves. However, other types of valves may be used to implement the liquid shutoff valves **2208***a*, **2208***b*. When a power connector pin **2214**, **2216** is inserted (e.g., fully inserted) into the sockets **2210**, **2212**, the power connector pin **2214**, **2216** displaces (e.g., unseats) a stem **2218** from a core **2220** of the valve **2208***a*, **2208***b*, which permits liquid to flow to and/or from the hose liquid cooling assemblies **1908-1914**. When the power connector pins **2214**, **2216** are removed or partially removed, the stems **2218** are forced back into the cores **2220** and stop flow of liquid.

A hose **2222** of the liquid cooling assemblies **1908** is coupled to the fluid socket **2209***a* via a ferrule **2224**. The example the example sockets **2209***a*, **2209***b* and/or the hoses **2222** include hose barbs to secure the hoses **2222**. However, other methods of securing the hose to the sockets **2209***a*, **2209***b* may be used, such as clamps, compression fittings, or any other hose fittings.

The example power and liquid transfer assembly **1916** may operate as described above with reference to the power and liquid transfer assembly **216** of FIG. **8**.

As illustrated in FIG. **23**, the liquid cooling assembles **1912**, **1914** may be secured to the power and liquid transfer assembly **1916** at least partly using a cover **2302** configured to prevent disconnection of the power connector pins **2214**, **2216** from the power and liquid transfer assembly **1916**. For example, the cover **2302** may include a shoulder and/or other features configured to prevent movement of the power connector pins **2214**, **2216** away from the power and liquid transfer assembly **1916**. The cover **2302** may be secured by a fastener, such as a bolt, and/or any other type of fastener or fastening technique.

While the present method and/or system has been described with reference to certain implementations, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the present method and/or system. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from its scope. For example, systems, blocks, and/or other components of disclosed examples may be combined, divided, re-arranged, and/or otherwise modified. Therefore, the present method and/or system are not limited to the particular implementations disclosed. Instead, the present method and/or system will include all implementations falling within the scope of the appended claims, both literally and under the doctrine of equivalents.

All documents cited herein, including journal articles or abstracts, published or corresponding U.S. or foreign patent applications, issued or foreign patents, or any other documents are each entirely incorporated by reference herein, including all data, tables, figures, and text presented in the cited documents.

What is claimed is:

1. A welding torch, comprising:

a first contact tip configured to conduct welding current to a consumable electrode;

a second contact tip configured to conduct preheating current to the consumable electrode;

a plurality of liquid cooling assemblies configured to conduct the preheating current and to conduct the welding current to the consumable electrode;

a first socket having a first fluid valve and configured to permit fluid transfer with a first one of the liquid cooling assemblies when the first fluid valve is open; and

a second socket electrically coupled to the first socket, wherein the first one of the liquid cooling assemblies comprises a first power connector pin configured to be inserted into the first socket and the second socket to transfer the fluid and to be electrically coupled to the second socket, the first fluid valve configured to open when the first power connector pin is inserted into the first socket and to close when the first power connector pin is removed from the first socket.

2. The welding torch as defined in claim **1**, wherein the plurality of liquid cooling assemblies comprises:

a first liquid cooling assembly configured to conduct the welding current; and

a second liquid cooling assembly configured to conduct the preheating current.

3. The welding torch as defined in claim **2**, wherein the first liquid cooling assembly is configured to conduct the preheating current.

4. The welding torch as defined in claim **1**, further comprising a power connector pin retention mechanism configured to physically resist removal of the first power connector pin from the first socket and the second socket when engaged.

5. The welding torch as defined in claim **4**, further comprising a retaining ring configured to attach the power connector pin retention mechanism to the first power connector pin.

6. The welding torch as defined in claim **1**, further comprising:

a third socket having a second fluid valve and configured to permit fluid transfer with a second one of the liquid cooling assemblies when the second fluid valve is open.

7. The welding torch as defined in claim **1**, wherein the second socket comprises a plurality of contacts arranged circumferentially around an interior surface of the second socket, the plurality of contacts configured to contact the first power connector pin to transfer at least one of the welding current or the preheating current.

8. The welding torch as defined in claim **1**, wherein the plurality of liquid cooling assemblies comprise:

a first liquid cooling assembly configured to conduct the welding current and to provide a return path for the preheating current; and

a second liquid cooling assembly.

9. The welding torch as defined in claim **1**, further comprising a welding assembly comprising the first contact tip and the second contact tip, the welding assembly fluidly coupled to the plurality of liquid cooling assemblies.

10. The welding torch as defined in claim **1**, wherein a first one of the liquid cooling assemblies comprises:

an inner conductive layer configured to conduct at least one of the welding current or the preheating current; and

an insulative layer exterior to the inner conductive layer.

11. The welding torch as defined in claim **10**, wherein the first one of the liquid cooling assemblies further comprises an outer protective layer exterior to the insulative layer.

12. The welding torch as defined in claim **1**, further comprising a power and liquid transfer assembly configured to be fluidly and electrically coupled to the plurality of liquid cooling assemblies and, when fluidly and electrically coupled to the plurality of liquid cooling assemblies, to transfer current and coolant with the plurality of liquid cooling assemblies.

13. The welding torch as defined in claim **12**, further comprising a securing mechanism configured to secure the power and liquid transfer assembly to the plurality of liquid cooling assemblies.

14. The welding torch as defined in claim **12**, further comprising a torch neck configured to detachably attach a welding assembly to a torch body, the welding assembly comprising the first contact tip and the second contact tip, the plurality of liquid cooling assemblies being mechanically coupled to the torch neck.

15. The welding torch as defined in claim **14**, wherein the power and liquid transfer assembly is mechanically coupled to the torch body.

16. A welding torch, comprising:

a first contact tip configured to conduct welding current to a consumable electrode;

a second contact tip configured to conduct preheating current to the consumable electrode;

a plurality of liquid cooling assemblies configured to conduct the preheating current and to conduct the welding current to the consumable electrode; and

a weld cable configured to conduct the preheating current, welding gas, and the consumable electrode to the welding torch.

17. The welding torch as defined in claim **16**, wherein the weld cable is an air-cooled or gas-cooled cable.

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